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THE CENTURY IN PHOSPHATES AND FERTILIZERS

A Sketch of the South Carolina Phosphate Industry

BY

PHILIP E. CHAZAL E. M.

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Professor Charles U. Shepard, Jr.

THE CENTURY

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A Sketch of the South Carolina Phosphate Industry

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The following sketch of the Phosphate and Fertilizer Industry of South Carolina was prepared for the Centennial Edition of the News and Courier, issued April 20, 1904, and to this fact are due its form and some of the matter included, of a general rather than a local character.

It contains some necessary corrections, and a few additions which, it is hoped, will add to its interest and value.

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THE CENTURY

IN

PHOSPHATES AND FERTILIZERS

A SKETCH OF THE SOUTH CAROLINA PHOSPHATE INDUSTRY.

The phosphate region of South Carolina lies along the coast, and practically parallel to the shore line, for a distance of about seventy miles, extending from the Wando River, on the north, to Broad River, on the south, and at a distance of from ten to thirty miles from the ocean.

North of this region occasional specimens have been reported in this State, notably in the neighborhood of Georgetown, but no deposit has ever been developed. The beds discovered still further north, in North Carolina, are of low grade and no commercial importance.

South of Broad River, with the exception of a few isolated specimens found in some of the Georgia coastal rivers, a similar condition of affairs prevails until the State of Florida is reached. Even here the deposits located on the eastern coast, unlike the valuable beds of the western and central portions of the State, have proven of no commercial value.

The phosphate beds are, of course, not continuous within this region, unless, indeed, they are connected at depths so far not reached in prospecting. The level character of the beds, however, and their modes of occurrence make this continuity extremely improbable and practically non-existent. In any event, it is a matter of no practical importance under existing conditions, and of interest only in connection with the consideration of the mode of formation of the deposits.

No State examination has ever been made of the phosphate region. In 1870 Professor N. S. Shaler was sent by the United States Coast Survey to make explorations to outline the limits of the deposits, presumably in the rivers and was so engaged for about two years. The work, however, was then suspended,

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on account of legal difficulties about publishing its results in the reports of the Coast Survey, and no such publication was made.

It was not until Professor Charles U. Shepard, Jr., of Charleston, caused to be prepared, under his direction, a map of the lower portion of the State setting forth the results of his extended personal explorations and investigations, together with information gathered by him from various sources, that any attempt was made to outline the limits of the phosphatic area. The map so prepared was confined to the coastal region of the State, showing its main topographical features, and having outlined in red the areas within which phosphatic deposits existed at a depth of six feet or less, this depth being considered at that time as the extreme limit of profitable exploitation.

In 1881 this map was revised by Professor Shepard in connection with an article by him on the phosphate industry of the State, which was published in the annual report for that year of the Commissioner of Agriculture of the State.

This report, for which there was a great demand, is out of print and the map is no longer procurable, very unfortunately, as it remains practically the only one ever issued, the smaller, uncolored maps given in several national publications being in reality copies thereof, and, except in one instance, uncredited.

SUB-DIVISIONS OF PHOSPHATE REGION.

The phosphate deposits, as has been said, do not lie in continous beds through the whole phosphate region, but occur at intervals within this territory.

Beginning from their Northern limit, however, the principal beds may be divided into general groups, which may be designated as follows:

Wando River beds.
Cooper River beds.
Northeastern Railroad and Mount Holly beds.
Ashley River beds.
Stono River beds.
Edisto and Ashepoo beds.
Coosaw River beds.
Beaufort River beds.

WANDO RIVER BEDS.

In the headwaters of this river there was a considerable deposit of rock of fair quality, much of which was hand-mined by

the Marine and River Company with oyster tongs and rakes. Intermixed with the rock occurred large numbers of fossil bones, from which it was, at times, very difficult to distinguish the former, on account of its remarkably fine-grained structure. Large quantities of menillite, false opal, were also found in this river. The transition to this from the rock was so gradual, and the external resemblance between them so close, that a considerable amount of this worthless material was mined and lightered to Charleston.

The land beds of this vicinity never proved of value, the attempts to mine them having been generally unsatisfactory.

COOPER RIVER BEDS.

The land deposits along this river have not proven remunerative. Though some of the rock is of good quality, it has never been found in sufficient quantity to justify exploitation.

NORTHEASTERN RAILROAD AND MOUNT HOLLY BEDS.

Some bodies of rock of high quality have been mined in this locality. In spite of the fact that a portion of the rock was in the form of sheets, requiring more or less blasting, and that it also contained a larger proportion of fine rock than is usual in most Carolina deposits, the mining on some of the tracts was very highly profitable.

Most, if not all, of the best deposits have been exhausted. There still remains, it is true, a considerable phosphatic area, but the small size of some of the deposits and the poor or variable character of the material contained in the others have made and make their profitable working practically impossible under past and present conditions, or any that are likely to obtain for many years.

In this neighborhood the best rock is of a rich brown color. The poorer grades are generally lighter. Some of the small rock, or fines, resembles very closely the darker Florida land pebbles, but its quality is very much poorer. At one point, near Ten-Mile Hill, there is found a very light colored rock which is so soft and friable that it suffers great loss when handled by the ordinary methods.

ASHLEY RIVER BEDS.

The land beds of this group have up to this time furnished by far the greater part of the output of land rock. This deposit lies on both sides of the Ashley River. East of the river it began at

a point about a mile below Bee's Ferry (C. and S. R. R. bridge), and extended to a point just above the present Ashley Works, a distance of some ten miles.

The upper portion of the deposit has not proven of much value, on account of insufficient quantity or too great depth below the surface, and comparatively little rock has been taken therefrom.

The remainder of the deposit, however, has been one of the main sources of supply, a very large amount of high grade rock having been mined therefrom, generally at very moderate depths, the rock at some points lying practically at the surface.

So far as is known the rock on this side of the river, below Bee's Ferry, may be regarded as exhausted. Above this point, although the bulk of the deposit has been mined, there is still a considerable amount remaining.

On the west bank of the river and reaching from it over towards Stono River, Rantowle's Creek and the Bear Swamp road, and at points beyond this road, there is a large and very valuable body of rock land of good quality and moderate depth.

Although this locality has been the scene of almost continuous mining from the commencement of the industry and very large quantities of rock have been removed, the area of its rock beds was so great that there has not been the same proportion of removal as on the opposite bank of the river.

With the exception of a comparatively small amount now being mined in the Ashepoo-Edisto neighborhood, the Ashley River beds are at present the sole source of supply of land rock.

The rock from these beds varies very much in hardness and color. Its phosphatic content is generally high. At points, however, the percentages of oxide of iron and alumina are above the average. On the other hand, in the marsh rock, along Stono River, the amount of these ingredients is generally lower, as is to be expected from its resemblance to river rock.

Stono River was the seat of the main operations of the old Marine and River Mining Company, the first of the river companies chartered by the State. The operations of this company were large and long continued and the bulk of the deposits lying at the bottom of the stream, sometimes covered with mud and sand, was mined and shipped.

Doubtless from the more or less irregular character of submarine operations, isolated spots were left untouched. Moreover, the washers used by the Marine and River Company were not equipped to handle rock embedded in tenacious clay. One

such bed, left practically untouched, is now being mined by the Stono Mining Company and, it is said, with good results.

In the lower portion of the river, near the bend, there is said to be a considerable bed of sheet rock, containing much carbonate of lime, and being so hard as to necessitate blasting, which was the seat of operations of the reorganized Marine and River Company.

Stono River rock was generally hard and black or very dark. It was sometimes coated with a highly polished enamel, which gave it an extremely attractive appearance.

As was the case with most of the river rock, it was admirably suited for the manufacture of superphosphate, in spite of the fact that its average grade was lower than the average of the land and most other river rocks.

Between Rantowle's Creek and the Edisto River, a distance of about twenty miles, there is a considerable stretch of land in which, although rock deposits exist at various points, investigations have failed to develop beds of any consequence until the Edisto River is reached, a state of affairs for which it is difficult to offer any explanation.

On the north bank of the Edisto, some little distance above the tracks of the Charleston and Savannah Railway, a considerable amount of rock has been taken out and a certain area is still left, some of it said to be very valuable, though no mining has been done there for some years past.

Higher up the river, on the same side, some heavy and, it is stated, rather extensive deposits occur, but they are of such poor quality as to be valueless, except under conditions of deficiency of supply not likely to obtain for many years, if ever.

EDISTO RIVER ROCK.

Some comparatively unimportant deposits are found in the bed of this river. For many years the great distance of water transportation would have prevented their utilization, had their quantity been sufficient. Even since the establishment of a local factory, no attempt has been made to utilize them, doubtless on account of the greater attractiveness and cheapness of the neighboring land deposits.

EDISTO-ASHEPOO BEDS.

On crossing the Edisto River a different state of affairs is met with. Between this river and the Ashepoo there is a large area in which occur numerous deposits of rock valuable on account

of its unusually fine quality, running as high at times as 64 per cent. of bone phosphate of lime in the washed, though unburnt condition, and averaging over 62 per cent. of this ingredient.

The very general thinness of the overburden is a conspicuous and valuable characteristic of these deposits.

They lack the uniformity of the Ashley River beds, varying very much in thickness, sometimes in very short distances, and with a greater tendency to blank spots. The general high quality of the rock however, the very small amount of excavation necessary, as well as the fact that a large proportion of the territory remains untouched, except for prospecting purposes, make it one of the most valuable localities now left in the State. After the exhaustion of the more accessible lands now being excavated, its present high value must be greatly enhanced.

TERRITORY SOUTH OF THE ASHEPOO.

South of the Ashepoo River, no land deposits, at least none of consequence, have been found, except on the islands bordering on the Coosaw River and its tributaries.

On South Williman's and Chisolm's islands, mining was carried on at greater or less intervals for many years.

On South Williman's Island, mining operations were never resumed after the cyclone of 1893. How much rock is left on the island is not known.

On Chisolm's Island there were deposits of land and marsh rock. The land mining, so far as can be learned, did not prove profitable, the quality not being of the highest and the overburden in some parts heavy. Attention was soon turned to the more uniform, shallow and high grade marsh rock of this deposit. A comparatively small portion was banked in and mined.

Chisolm's Island, in time of storm, lies in a very exposed position, the Coosaw River, which bounds it along its whole length, being in point of fact an arm of the sea rather than a river, and being noted for the roughness of its waters even under ordinary conditions.

The construction and maintenance of banks is thus made troublesome and very expensive, the problem being further complicated by the fact that the best of the deposits lies immediately on the river edge of the marsh, appearing to be virtually a continuation of the neighboring river deposit. It would seem that the only profitable method of working would be by dredge from the river, and after the purchase of the property by the

Coosaw Company, in the last half of the nineties, this course was followed, to what extent is not known.

Chisolm's Island contained, also, several more or less bold creeks. containing rock, which were the subjects of prolonged litigation between the owners and the State, the verdict having been in favor of the latter.

THE COOSAW RIVER BEDS.

The Coosaw deposits have held, in regard to the river rock, the position occupied by the Ashley River beds in the exploitation of land rock. Being in reality, as has been said, a wide arm of sea, its deep bed was a receptable for the drift of a large area and its bottom was practically rock covered.

The rock is found in great beds of nodules and boulders, and is black, hard, and of fine quality when free from marl. Since the exhaustion of the main beds, the usual difficulties of dredging have been increased manifold by the necessity for dealing with the more or less mixed material which is present in large quantities.

Most of the smaller lateral streams have been worked out, and the only mining being carried on any where in this neighborhood is in Coosaw river proper.

BEAUFORT RIVER BEDS.

This river contained several good beds of rock of somewhat inferior grade, so far as analysis in concerned, but making, with the formula in use at the time, a super-phosphate equal in grade to those obtained by the treatment of the usual standard rocks. There were also one or more beds of better grade, but they were very deep and difficult to mine.

PHYSICAL CHARACTERISTICS OF THE ROCK.

Carolina rock is essentially nodular, the nodules varying, it is true, from fines the size of a pea to boulders of two thousand pounds, with an average weight, however, of only a few pounds. It occurs sometimes in flat cakes, more or less easily breakable into their component nodules, and, more rarely, in sheet-like strata, in which the nodules, if the mass ever existed as such, have been so cemented together in the process of phosphatization, that they can no longer be distinguished, and which offer an unbroken, hard, and frequently polished and resistant surface, yielding only to blasting. The nodules are sometimes kidney-shaped, oval, or almost rounded, more generally irregu-

larly shaped, and, at times, somewhat angular, this variation in shape depending, doubtless, on the amount of attrition they received when drifted together by the water currents, by which they were collected into beds.

They are sometimes almost solid, but more generally full of cavities and perforations, probably due to slight variations in the chemical composition of the original masses, and to the action of marine boring animals.

The surface is sometimes very highly polished, as if covered with a lustrous enamel. Generally, however, it is dull and rough, the granular structure of the mass being clearly visible. The internal structure of the nodules is generally granular and identical with that of the Eocene marls. Very rarely, somewhat laminated masses are found. When fractured, the masses sometimes glisten with small silicious particles. The structure is entirely amorphous, no evidences of crystallization being discernible.

The porosity of the rock is great, especially where the polished enamelled surface is wanting. After washing, the rock may contain 15 per cent. of moisture, though on air-drying this generally falls below 10 per cent.

The color is extremely varied. The river rock is generally dark-colored, black or grayish black. The land rock is of lighter hues, varying from light gray or yellowish gray through reddish shades (due generally to an increased amount of oxide of iron), to light brown, and a rich dark chocolate brown. The marsh rock is generally dark, resembling the river rock more closely than the land rock. Some varieties of the marsh rock, indeed, appear to be identical with that of the neighboring river deposits.

When calcined or properly kiln-dried, the rock yields easily to crushing and grinding, and, especially in the absence of the small water-worn quartz pebbles occurring to a greater or less extent in most of the deposits, may be reduced without difficulty to an extremely fine state of division. Indeed, this process may be carried so far that most of the product will float in the air.

So great is the ease, comparatively speaking, with which this can be done, that it was at one time thought feasible to supplant thereby the generally accepted method of chemical subdivision with sulphuric acid, and considerable efforts were devoted to this end before the advocates of the theory became satisfied that it was neither practical nor economical.

When ground, the color of the resultant powder varies from a light yellowish gray for land rock, to a darker, though still light gray when derived from river rock. In all cases the color of the powder is lighter than that of the unground nodules.

The specific gravity of Carolina rock varies from 2 to 2½, averaging according to a large number of determinations made by Professor Charles U. Shepard, Jr., about 2.4. The density of the river rock is generally greater than that of the land varieties.

The river rock is also generally harder than land rock, though this is not invariably the case, some varieties of the latter, notably the sheet rock mentioned above, being very hard and resistant, at least at the surface.

This hardness varies between 3.5 and 4, though one very soft variety, identified by Professor Charles U. Shepard, Sr., as epiglaubite, had a hardness of only 2.

The structure of the nodules is very seldom uniform. It is generally densest and hardest at the surface, the interior growing softer and more granular towards the centre, the color also varying. The lumps also contain, though very rarely, internal cavities (not perforations) containing sand or clay.

THICKNESS OF STRATA.

The rock lies in strata of greater or less thickness, varying from two or three inches to thirty or thirty-six inches, the latter, however, being very unusual. The average thickness of the workable beds may be estimated at from 8 to 9 inches, deposits of 12 to 16 inches being considered unusually good.

The thickness of the stratum, however, is by no means necessarily an indication of the yield per acre, and therefore is not the only factor to be considered. With varying conditions of density, solidity and greater or less freedom from mixture with clay or sand, it is evident that different deposits with the same thickness of stratum may yield very different returns.

Ignorance or forgetfulness of this important, though simple and apparently self-evident fact, has been the cause of frequent error and loss.

YIELD PER ACRE.

The yield of the land deposits varies from three hundred to twelve and fifteen hundred tons per acre, with an average of between seven hundred and eight hundred tons.

ODOR OF THE ROCK.

Pieces of freshly fractured Carolina rock, when rubbed together, emit a peculiar odor bearing a slight resemblance to burning horn. The odor generally increases with the density of the rock and the content of organic matter. It is probably due to the vaporization of some oily constituent of the latter ingredient by the heat of friction.

CHEMICAL COMPOSITION OF THE ROCK.

As would be expected from what has been said as to the great differences in the physical characteristics of the rock, and its entirely amorphous character, its chemical composition varies greatly.

The bulk of the mass is made up of phosphoric and carbonic acids, in combination with lime, and of sand or insoluble silicious matter, and the grade and consequent value of the rock is determined by the fluctuations in the amounts of these ingredients.

The rest of the mass is made up of sulphuric acid, iron pyrites, (about 1 per cent.), fluorine, chlorine, iodine, magnesia, oxides of iron and manganese, alumina, potash, soda, organic matter and water, with occasional faint traces of other ingredients.

On account of its variability and lack of uniformity of composition, it is impossible to give any average analysis, which will serve as an exemplar of the whole.

A table taken from a lecture delivered by Professor Charles U. Shepard, Jr., in 1879, on "South Carolina Phosphates," will serve to give an idea of the range of the various more important constituents. This table, which Professor Shepard stated was the result of many hundred analyses of clean, dry samples of rock, is as follows:

(1) Phosphoric acid	25	to	28 p. c.
(2) Carbonic acid	2½	to	5 p. c.
Sulphuric acid	½	to	2 p. c.
Lime	35	to	42 p. c.
Magnesia	traces	to	2 p. c.
Alumina	traces	to	2 p. c.
Sesquioxide of iron	1	to	4 p. c.
Fluorine	1	to	2 p. c.
Sand and silica	4	to	12 p. c.
Organic matter and combined water	2	to	6 p. c.
Moisture	½	to	4 p. c.

(1) Equivalent to bone phosphate of lime, 55 to 61 per cent.
(2) Equivalent to carbonate of lime, 5 to 11 per cent.

The organic matter is nitrogenous, containing occasionally as high as a quarter per cent. nitrogen.

Developments by mining, or extensive prospecting carried on since the date of preparation of this table, would seem to necessitate some changes therein,

The higher limit for bone phosphate of lime is somewhat low, there being in the Edisto-Ashepoo region deposits yielding 64 per cent. of this ingredient.

Some quite high grade material, too, has shown as much as 13 per cent. of sand, and the higher limit for carbonate of lime is also somewhat low in the light of the experience of recent years.

Comparatively few complete analyses of Carolina rock are at present accessible, and it may therefore be of interest to present a few of these, as well as some partial analyses, showing the grades of the material occuring at different localities.

ANALYSIS OF LAND ROCK FROM BULOW MINES.

(Made by Dr. W. D. Wamer, Assistant to Professor Charles U. Shepard Jr.)

	P. C.
Moisture	2.43
Organic matter and water of combination	5.68
(1) Phosphoric acid	27.23
Sulphuric acid	1.45
Carbonic acid	3.05
Lime	39.10
Magnesia	traces
Oxide of Iron	1.38
Alumina	0.40
Silicious (insoluble) matter	13.03
Fluorine, chlorine and other ingredients, undetermined	5.25
	100.00

(1) Equivalent to 59.44 per cent. bone phosphate of lime.

The following analysis of, unfortunately, a low grade rock, was made by Professor R. Fresenius, the celebrated German chemist, and is of very great interest.

No record is at hand of the variety of rock represented by the analysis, but from the results it would appear to have been a sample of river rock.

	P. C.
Lime	39.40
Magnesia	0.49
Soda	0.69
Potash	0.07
Alumina	0.62
Sesquioxide of iron	0.56
Iron	1.37
Sulphur	1.57
Sulphuric acid	0.53
Phosphoric acid	24.64
Carbonic acid	4.54
Chlorine	0.02
Fluorine	3.24
Silica and sand	16.38
Moisture expelled at 100° C	1.83
Moisture expelled at red heat	4.66
Organic matter	0.75
Total	101.36
Correction for oxygen	1.36
Corrected total	100.00

Professor Fresenius combined these ingredients as follows:

	P. C.
Bone phosphate of lime	53.790
Fluoride of calcium	6.050
Chloride of calcium	0.035
Sulphate of lime	0.900
Carbonate of lime	9.090
Carbonate of magnesia	1.030
Soda	0.690
Potash	0.070
Alumina	0.620
Oxide of iron	0.560
Silica and sand	16.380
Pyrites	2.940
Water at 100° C	1.830
Water at red heat	4.660
Organic matter and loss	0.755
	100.000

Professor Fresenius considered the soda, potash, alumina and oxide of iron as combined with silicic or humic acid.

The low amount of organic matter shown in this analysis is very abnormal in Carolina rock, a similar result never having come under the observation of the writer. Exactly what is meant by the term "water expelled at red heat" is also not clear. The water of combination or crystallization of rock is given off at a temperature somewhat above the boiling point, and very far below red heat.

So low a percentage of organic matter could have been obtained only in a sample of rock that had been highly calcined, in which case all of the water of crystallization, as well as a considerable part of the carbonic acid, would have been expelled. It seems almost certain that a clerical error was made in reporting the analysis, and that the results should be "organic matter expelled at red heat, 4.66 per cent," and "moisture, etc., 0.755 per cent."

The following table of analyses, made by Professor Shepard in the early period of development of the industry, is of great value and interest as showing the results attained at that time.

In the table as presented here, several errors that have crept into some previous publications have been corrected, and, for the sake of comparison, the percentages of bone phosphate of lime, calculated on the dry basis, have been added:

	Stono River—Light Colored Rock	Stono River—Darker Variety of Rock.	Stono River—A Boulder weighing 1,590 pounds.	Ashley River Land Deposit—Hot air dried, cargo sample	Cooper River—Land deposit.	Chisolm's Island—Hot air dried, cargo sample.	Bull River—Hot air dried, cargo sample.	Coosaw River—Hot air dried, cargo sample.	Coosaw River—Hot air dried, cargo sample.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Moisture at 100° C	3.68	.....	1 50	0.00	} 10 07	0.84	0 79	0.57	0 66
Organic matter and combined water	4 78	.....	5 59	5 26		4.22	5.80	4.31	3.75
Carbonic acid	4.68	4.28	3.89	4.47	3.55	3.54	3.61	3.79	4.34
Equivalent to Carbonate of lime	10.64	9 73	8 84	10.16	8 06	8 04	8.20	8.61	9 86
Phosphoric acid	24.61	26.68	25.75	27.01	27 11	27.26	25.14	27.26	26.78
Equivalent to bone phosphate of lime	55 91	58 24	56.21	58.95	59.18	59.51	54.88	59.51	58.46
Sand	11.55	12.41	11 37	11.37	15 39	9.06	13.30	9.06	11.77
Bone phosphate of lime on dry basis	58 04	. ..	57.07	58.95	...	60 00	55.32	59.85	58.85

ROCK FROM UPPER WANDO RIVER.

	P. C.
Moisture	3.85
Organic matter	4.81
Carbonic Acid	4.89
Carbonate of lime	11.11
Phosphoric acid	25.14
Bone Phosphate of lime	54.88
Sand and insoluble matter	12.06
Bone phosphate of lime, dry basis	57.08

WANDO RIVER—OPPOSITE CAINHOY.

	P. C.
Moisture	4.79
Organic matter	3.45
Carbonic acid	3.36
Carbonate of lime	7.64
Phosphoric acid	22.36
Bone phosphate of lime	48.81
Sand and insoluble matter	24.02
Bone phosphate of lime, dry basis	51.26

NORTHEASTERN R. R. DEPOSIT—NEAR MOUNT HOLLY.

(Average of four analyses of crude, clean rock.)

	P. C.
Moisture	0.91
Phosphoric acid	26.98
Bone phosphate of lime	58.92
Sand and insoluble matter	9.70
Bone phosphate of lime, dry basis	59.45

The carbonate of lime in these samples was small in amount and was not determined.

NORTHEASTERN R. R. DEPOSIT—NEAR MOUNT HOLLY.

(On dry basis.)	P. C.
Bone phosphate of lime	59.35
Carbonate of lime	12.28
Sand and insoluble matter	6.57
Oxide of iron and alumina	4.13

FINES ROCK—NORTHEASTERN R. R. DEPOT—ABOVE OTRANTO,

(Average of six analyses.)

(On dry basis.)	P. C.
Phosphoric acid	23.88
Bone phosphate of lime	52.43
Sand and insoluble matter	18.96

The carbonate of lime in one of these samples was 16.43 per cent.

NORTHEASTERN R. R. DEPOT—BETWEEN JUNCTION AND TEN MILE HILL.

(On dry basis.)	P. C.
Organic matter	6.58
Carbonic acid	3.51
Carbonate of lime	7.98
Phosphoric acid	26.68
Bone phosphate of lime	58.25
Sand and insoluble matter	11.89

EDISTO REGION—DEPOSITS WEST OF RIVER.

(Average of over 100 analyses made by Shepard Laboratory.)

(On dry basis.)	P. C.
Bone phosphate of lime	60.46
Carbonate of lime	9.64
Sand and insoluble matter	9.16
Oxide of iron and alumina	3.62

The bone phosphate of lime in these samples ranged from 58.41 per cent. to 63.86 per cent.

EDISTO-ASHEPOO REGION—NEARER ASHEPOO RIVER.

(Average six analyses.)

(On dry basis.)	P. C.
Bone phosphate of lime	61.74
Carbonate of lime	11.01
Sand and insoluble matter	6.88
Oxide of iron and alumina	2.08

EDISTO-ASHEPOO REGION—NEAR ASHEPOO RIVER.

(Average five analyses.)

(On dry basis.)	P. C.
Organic matter	5.87
Carbonic acid	3.78

Carbonate of lime	8.59
Phosphoric acid	28.47
Bone phosphate of lime	62.14
Sand and insoluble matter	7.75

BEAUFORT RIVER ROCK.

(Average two analyses.)

(On dry basis.)	P. C.
Organic matter	3.42
Carbonic acid	1.71
Carbonate of lime	3.90
Phosphoric acid	24.51
Bone phosphate of lime	53.51
Sand and insoluble matter	22.27

In many of the nodules, or lumps, of rock the phosphoric acid is not uniformly distributed through the mass. As a general thing the outer shell, especially where this is enamelled and harder than the core, contains more phosphoric acid than the latter, sometimes to the extent of 1 per cent. or more.

It is important to emphasize the fact that the above analyses, except in the cases of cargoes, represent crude rock, carefully washed and, generally, dried, but neither burnt nor calcined.

In the early days of the industry the rock was dried in covered bins, open at the front, by hot air distributed through perforated pipes laid under it near the bottom of the piles.

The drying action was necessarily very uneven. The rock next to the pipes was thoroughly burnt and frequently calcined, particularly near the point of entrance of the hot air, where the heat was, of course, greatest. Toward the opposite end of the shed, and as the distance of the rock from the pipes increased, the heat and drying action diminished very materially, so that the bulk of the mass received little more than a fairly thorough drying, while a smaller portion was practically unaffected. In addition to this the cost of the pipes was great and their durability small.

This method was ultimately abandoned, and the system now in use was adopted, consisting, briefly, in burning the rock, in sheds, open on all sides, on wood carefully piled to permit a proper draft. The heat evolved is intense, that furnished by the wood being materially increased by the combustion of the organic material of the rock, and also by the formation and combustion of water gas.

Where the process is properly conducted, all of the rock, except a small thickness on the surface and towards the sides, is more or less burnt, while the portion at the centre and near the bottom of the piles is more or less calcined, By this method of drying, the moisture content of the mass, instead of being nearly 2 per cent., as with the old method, is frequently under one-half of 1 per cent.

The amount of carbonic acid gas expelled is also greater than under the old conditions. As a consequence, the grade of the rock, as shown by its content of bone phosphate of lime, is materially increased, an increase which is evidenced by the fact that the same rock which was formerly sold on a minimun guarantee of 55 per cent., and afterwards 57 per cent. of this constituent, is now required to meet a standard of 60 per cent.

In considering, therefore, the analyses which have been given above it is important to bear these facts in mind and to remember, for example, that a rock running 60.46 per cent. of bone phosphate of lime, like the crude Edisto rock, the analysis of which is given above, would readily yield, after calcination, 64 to 65 per cent. of that constituent.

EXTENT AND QUANTITY OF THE DEPOSITS.

In the absence of a systematic survey of the marine and river territory, and with the necessarily imperfect knowledge of the details of the land beds prevalent in the early period of the industry, the data necessary for an accurate estimate of the extent and probable output of the deposits were largely lacking.

The estimates then made were therefore based on general considerations and, with the varying conditions of occurrence and availability assumed, were very widely apart, some indeed being scarcely more than wild guesses.

The information afforded by the continued operation of the land and river deposits, the increased knowledge, in a general way, of the former, and the practical exhaustion of the bulk of the latter have of course lessened to a considerable extent the difficulties of the situation.

In point of fact, however, it is only within the last few years that some of the largest land properties have been prospected with any degree of accuracy, and it having been impossible, up to the time of the former publication of this article, (April 1904), to obtain the results thus arrived at all that could then be reliably stated was that notwithstanding the large amount of

material already excavated, (7,143,216 tons of land rock and 4,628,158 tons of river rock, as shown by the valuable statistical tables prepared by Major E. Willis for the Centennial issue of The News and Courier), there still remained a very large amount of rock, especially of the land variety, sufficient to furnish a supply for many years.

Since that publication, the writer has obtained private information which seems to justify him in estimating the amount of rock remaining in the land deposits at between 9,000,000 and 11,000,000 tons.

Prominence has also been recently given to the claim that there are rock beds of consequence in the marshes adjoining the rivers and estuaries of the State, but nothing definite is known, or has been disclosed, in reference thereto.

TOPOGRAPHY OF THE PHOSPHATE REGION AND OCCURRENCE OF THE BEDS.

As has been stated above, the phosphate beds of South Carolina lie entirely within the coast region, in what has been called the "Lower Pine Belt" of the State.

This coast region is freely intersected by numerous rivers, creeks and arms of the sea, the result being a series of low and, generally, long islands lying immediately on the ocean, and a chain of connected navigable waterways separating the islands from the mainland.

This chain of waterways, with the rivers and creeks flowing from the interior, offers a safe and economical transportation from the mines to the points of consumption or loading.

The average elevation of the region is very low, hardly exceeding ten feet above high water mark. Occasional elevations of twenty to thirty feet are found, but these are very rare.

Numerous marshes and swamps occur in the neighborhood of the various streams, and the low lands in the region, therefore, cover a large area. The phosphate deposits occur most generally in the "leads," probably old waterways, extending up from the streams, and this has been a controlling reason for the fact that the depth of the rock below the surface is generally small, and its excavation, therefore, rendered very economical.

The phosphate beds themselves are generally level, almost horizontal, and not following the contour of the surface, and hence the drainage of the trenches by which it is excavated is made comparatively simple. Where the ground rises the depth

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to the rock increases, and with the increase the availability of the rock comes into question.

It is scarcely possible to make an accurate estimate of the average depth of the rock below the surface. The average depth of the areas already mined would probably be between six and eight feet.

The rock beds are found at all depths, from a few inches down to twenty feet or more, in some few instances lying practically at the surface.

As has been noted, the depth has an important bearing on the cost of excavation. For many years the extreme limit of economical working was considered to be six feet, and practically no deposits of greater depth below the surface were mined. Improved methods and experience showed that this limit could be extended to greater depths, varying with the surface conditions, the character of the overburden, and the difficulty of handling it.

STRATIFICATION OF THE DEPOSITS.

In his article on "South Carolina Phosphates" (1880) Professor Shepard, whose long connection with the phosphate industry of the State, and whose personal explorations and investigations of both its marine and land deposits, especially, however, of the former, gave him peculiar opportunities of observation over a wide extent of territory, gives the following description of the mode of occurrence of the "ordinary superficial beds of phosphate— those now worked."

"A—LAND DEPOSITS.

I. Soil and subsoil; a few inches to a foot in depth.

II. A light colored siliceous clay, iron stained in places, and containing much fine, transparent sand, and minute scales of silvery mica, with little calcareous matter—one foot or more in thickness.

III. (Wanting in the more superficial beds.) A blue, argillaceous (clayey) marl, probably altered marsh mud. It does not adhere to the tongue or give an argillaceous odor. Fragments of recent shells occur in this deposit. Its depth is about two feet.

IV. A thin layer of coarse sand—one to three inches in depth.

V. The phosphate nodules, in either a loose siliceous or a bluish or rich buff colored argillaceous marl, frequently accompanied with abundant fossil bones and teeth. The upper nodules are often harder, the lower softer, and at some land

localities exhibit a gradual transition, by loss of cohesion and decrease of phosphatic content, into

VI. A marl, highly phosphatic toward the rock-bed and occasionally containing twenty to thirty per centum of phosphates, but at the depth of a few inches containing only ten to twenty per centum of these constituents.

VII. Argillaceous or Arenaceous (sandy) marls, containing seven to ten per centum of phosphate.

"B—RIVER DEPOSITS.

Beneath the river deposits occur either:

I. A gray marl—sometimes in nodules resembling phosphate, with 5 per centum of phosphates, underlaid by

II. A white, hard marl, enclosing phosphatic grains, and containing three to five per centum of phosphates (Wando River;) or

I. A green sand—with some clay, and rich in black phosphatic grains, occurring with and beneath the phosphatic rock, containing 15 per centum of phosphates (Stono River;) or

I. Hard marls—poor in phosphates (one-half to one per centum,) unless their tops be coated with phosphate rock (Coosaw River.)"

DOUBLE STRATIFICATION.

An extremely interesting fact, especially in connection with the question of the deposition of the beds, is the occurrence of two superimposed strata of rock.

These occurrences have been reported at various points in the phosphate region, but their area has been generally so restricted that most of the observers, practical miners, have declined to believe them to be anything but parts of the same bed, with an accidental interposition of clay or sand.

Several instances that have come under the observation of the writer show clearly, in his opinion, the inaccuracy of this view.

Some years since, in examining some deposits on the upper edge of the Edisto region, two such instances were observed. On one tract there was a fairly large body of rock, of no very great thickness, which was found to analyze as follows:

(On dry basis.)	P. C.
Bone phosphate of lime	50.54
Carbonate of lime	12.17
Sand and insoluble matter	19.14
Oxide of iron and alumina	2.93

In one portion of the deposit there occurs at a few inches above the regular stratum, and separated from it, if the recollection of the writer is accurate, by a more or less sandy clay, another heavy seam, ten to eighteen inches in thickness, of a hard material somewhat resembling sandstone, which on analysis was found to contain:

(On dry basis.)	P. C.
Bone phosphate of lime	44.97
Sand and insoluble matter	31.22
Oxide of iron and alumina	3.01

On another tract, about a mile or so from the above, a similar double stratification is found, except that in the upper stratum the excess of silica is replaced by carbonate of lime. Unfortunately, owing to a press of work, no analysis was made of this material.

The most interesting occurence of the kind is found at the mines of the Bolton Mining Company. The deposits mined by this company have always been of great interest, as being the most extensively and highly developed instance of marsh mining in the state. The rock of these deposits, while partaking more of the character of river rock than of the land varieties, yet occupies an intermediate position between them.

At a point of one of the dredge cuts on this property there occurs a very clearly defined instance of a double seam, extending for a length of about three hundred feet along the line of the cut.

The average stratification at this point may be stated as follows:

a. Soil and mucky marsh mud—six to seven feet.

b. Sand—three feet.

c. Upper rock stratum—three to six inches in thickness, lying entirely in sand. The rock is solid, nodular, black and hard, like Stono River rock. The nodules vary in size from pieces three to four inches in diameter downward, being generally rather oblong in shape. With the rock occurs, almost persistently, a little rotten shell, generally in very small fragments.

d. Blue sandy clay—twelve to thirty-six inches.

e. Lower rock stratum—with an average thickness of about eight inches, entirely embedded in much sandy, blue clay. The rock is generally brown, sometimes black. Some pieces are partly brown, and partly black. It is not so hard or solid as the rock of the upper stratum.

It occurs chiefly in lumps of three or four inches in diameter, and is very much perforated, the perforations being entirely filled with the blue clay of the bed. At times these perforations are very small at the surface, and are seen only when the lumps are broken. The blue clay forms more than half of the mass of the seam.

f. Blue clay—six inches.

g. Marl.

At both ends of the three hundred foot line the rock strata come together, the intervening blue clay disappearing, and for more than a thousand feet, to the end of the present cut, the upper black stratum, with the slight intermixture of rotten shell, lies immediately on top of the lower stratum, the difference in physical appearance of the two being distinctly visible.

Apparently the lower stratum was first deposited in a shallow basin, its surface following more or less that of the marl and clay beneath. The depression, or shallow basin, thus formed was filled with blue clay, the thickness of which varied with the depth of the basin, the edges of which were left uncovered. Thus, when the upper seam was deposited, while separated from the lower, within the area of the basin, by more or less mud, it was in immediate contact with the lower stratum at the edges.

The following analyses of the rock from the upper and lower strata are of interest in showing the difference in character of the material, at least at one point of the occurrence, and as an evidence of the dual nature of the deposits. The samples were carefully hand washed and dried before analysis. In the case of the rock from the lower stratum, the permeation of the lumps by the clay made it necessary to break them into comparatively small pieces, in order to get rid of the latter, this being necessary to show the character of the rock material proper.

(On Dry Basis.)

	Upper Stratum. P. C.	Lower Stratum. P. C.
Carbonic acid	4.39	4.45
Carbonate of lime	9.98	10 11
Phosphoric acid	27.80	26.7⅞
Bone phosphate of lime	60.71	58.47
Sand and insoluble matter	10.46	12.68
Oxide of iron and alumina	1.75	1.76

MARL UNDER LOWER STRATUM.

(On dry basis.)

	P. C.
Carbonic acid	30.20
Carbonate of lime	68.64
Phosphoric acid	4.51
Bone phosphate of lime	9.84
Sand and insoluble matter	12.88

The rock of the upper stratum is exceptionally high in bone phosphate of lime, the quality of the lower stratum being as high as, if not higher than, the average of the best class of rock of this locality.

The mode of occurrence and the differences, both chemical and physical, between the two strata, as shown above, seem to point conclusively to an entirely separate deposition of the two seams, and to go far towards settling what has long been, as has been said, a much mooted question.

Similar instances are said to occur, though not to the same extent, at the old Wando Mines, near Bee's Ferry, and on the adjoining property of the Charleston Mining Company, but it has not been feasible to secure information in regard thereto sufficiently detailed to permit description.

GEOLOGICAL FORMATIONS OF THE CHARLESTON BASIN.

The calcareous strata of the Charleston basin, as outlined by Professor M. Tuomey, occur in an irregular area about seventy-five miles long and sixty miles wide, extending from the Santee River to the Ashepoo, and embracing within its limits the land phosphate deposits of the State.

The geological history of this basin has been carefully and fully treated, first by Professor Tuomey, (Report on the Geology of South Carolina," Columbia, 1846), and afterward by Professor Francis S. Holmes, ("The Phosphate Rocks of South Carolina," Charleston, 1870), their conclusions being based on their studies of the various formations of the basin, with the fossils occuring therein, and in the case of Professor Holmes, on the observations made during the boring of the old artesian well (Wentworth Street) in Charleston, which was commenced in1846 and ultimately carried to a depth of 1,260 feet.

Artesian wells subsequently sunk, one in 1872 to a depth of 323 feet at Sineath's Station, thirteen miles from Charleston, and the other in 1876 in Charleston (Citadel Green), and carried

to a depth of 1,970 feet, were both carefully studied, and have afforded valuable information as to the extent and occurrence of the several formations.

The results of the various observations may be briefly summarized, as follows:

The lowest formation so far reached is the Cretaceous. The marls and limestones of this formation outcrop on the Pee-Dee River, but (according to Holmes) were reached in the Wentworth Street well at a depth of 800 feet.

According to Professor James Hall, of the New York State Museum of Natural History, to whom the material obtained from the Citadel Green well was submitted for study and identification, the Cretaceous is reached at 600 feet below the surface, extending continuously from that point to the bottom of the well, a distance of nearly fourteen hundred feet.

While the marls of this formation, of a dark bluish gray color, contain only from 30 to 40 per cent. of carbonate of lime, the limestones are much richer, having from 60 to 75 per cent. of this constituent.

Immediately above the Cretaceous lies the Eocene, called by Ruffin, on account of its thickness and richness, "the great Carolinian marl bed." Its thickness was estimated by Holmes to be seven hundred feet, based on old well, but the results of the new well would indicate this estimate to be too high, the true thickness at that point being some five hundred feet. It is subdivided into the Santee, Cooper and Ashley marl beds.

The oldest and lowest of these are the Santee, composed principally of hard shells and corals or corallines forming Tuomey's "coralline bed of the Charleston basin." The marls of this group, white in color when dried, are of very high grade, containing in some cases as much as 97 per cent. of carbonate of lime, but averaging 94 per cent. of this ingredient.

The marls of the Cooper River beds, next in age to the Santee beds and lying above them, are harder than those of the Ashley beds, beneath which they occur, and richer in carbonate of lime, the amount of which varies from 42 per cent. to 95 per cent. in different varieties. As might be expected, however, they are poorer in bone phosphate of lime, of which they contain only from a trace to one and one-half per cent. (Tuomey, p. 236.)

The Ashley beds were estimated by Professor Holmes to be about two hundred and sixty feet thick. The marls composing them have from 36 to 76 per cent. of carbonate of lime, but contain from 6 to 9 per cent. of phosphate of lime.

The fossils of the Cooper and Ashley marl beds consist chiefly of remains of "cartilaginous fish, especially of the shark family, though they also contain numerous bones and teeth of cetaceans, or whale-like animals." (Holmes, p. 19.) Above the marl lie thin strata of sand and blue clay containing many fossil sharks' teeth and bones of cetaceans, forming what is known as "the Ashley fish bed."

Next in order come the Post-Pleiocene sands and the strata containing the phosphate nodules and, above these, clay, sand and alluvial deposits.

The phosphate deposits, from the identity of their fossil remains with those of the subjacent marl, were considered by Tuomey, to whom they presented themselves as "marl stones," as being of the same formation as the latter, (pp. 164, 165,) but after subsequent study, in the light of the development of scientific knowledge, they were located by Professor Holmes in the Post-Pleiocene age.

This, however, is not the only horizon showing phosphatic stones. One specimen taken from the depth of 1,840 feet in the Citadel Green well contained 64.88 per cent. of phosphate of lime, 5.68 per cent. of carbonate of lime, and 2.62 per cent. of sand and insoluble matter.

In the Sineath's Station well this occurrence was more frequent. Speaking of it, Professor Charles U. Shepard, Jr., (Rural Carolinian, August, 1873,) says:

"Phosphate of lime to the amount of 50 per cent. more or less, occurs in layers of large nodules at the depth of 26, 70 and 110 feet; and in pebbles at 280 and 312 feet; to the amount of 30 per cent. in comparatively large nodules at 104 and 125 feet, of over 5 per cent. in the upper layers of marl, gradually diminishing in amount with the increasing depth, until present only in traces in the stratum superior to that containing phosphatic pebbles (280 feet.) At greater depths than 280 feet the amount of phosphate appears to coincide with the greater or less per centage of the black phosphatic grains."

The table of analytical results accompanying this article is of great interest, and the Journal in which it appeared being generally inaccessible, it is reproduced here:

Depth of stratum.	Character of each stratum.	Phosphoric acid.	Equivalent in bone phosphate of lime.	Carbonic acid.	Equivalent in carbonate of lime.	Total lime.	Magnesia.	Sand and silica.
ft.		p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
17 to 20	Clay	0.42	0.92	4.73	10 75	*	*	70.00
26 to 30	Phosphatic nodules	26.79	58.48	4.00	9.09	*	*	4.82
do	Marl	3.07	6.70	26.46	60.14	39.90	0.75	18.92
34	Marl	3.01	6.57	26.64	60.54	*	*	17.13
46	Argillaceous marl	2.03	4.43	24.55	55.79	41.99	0.99	14.21
70	Phosphatic nodules	22 72	49.59	2.70	6.14	34.02	traces	27 19
85	Argillaceous marl	1.26	2 74	24.78	56.32	33.76	0.56	21.14
90	Argillaceous marl	1.51	3.30	24 20	55.00	*	*	13.77
104	Phosphatic nodules	13.38	29.20	17.30	39.32	42.08	1.09	12.61
110 to 112	Phosphatic nodules	23 60	51.52	2.53	5.75	35.82	0.25	23.26
do	Argillaceous marl**	10.65	23 24	15.67	44.70	43.52	traces	15.04
125 to 128	Phosphatic nodules	15.81	34.91	13.95	31.70	41.82	0.75	15.14
do	Hard marl	1.23	2.68	14.79	33.61	*	*	46.14
145	Argillaceous marl	traces	. .	16.87	38.34	23.70	*	31.50
170	Argillaceous marl	traces	....	22.74	51.68	36.59	traces	24.48
228	Argillaceous marl	traces		23 54	53.50	*	*	27.32
255	Argillaceous marl	traces	. . ....	22.22 21.26	50 50 48.32	35.68 34.86	* 0.37	26.02 27.06
280	Phosphatic pebbles	23.47	49.05	3.80	8.66	35.94	traces	14.48
286	Argillaceous marl	0.60	1.31	27.63	62.79	40.52	*	18.16
287 to 290	Marl and phosph. grains.	5.96	13.01	*	*	27.44	2.95	26.19
300 to 305	Argillaceous marl	3.37	7.37	18.18	41.32	37.35	traces	16.00
305 to 306	Sandy marl	0.90	1.96	20.23	45.98	30.48	traces	43.55
307	Sandy marl	0.80	1.75	13.93	31.66	21.99	*	56.17
309 to 311	Hard marl	0.63	1 37	19.39	44.06	30.36	1.05	41.09
312 to 313	Phosphatic pebbles	27.72	60.52	3.85	8.75	43.42	traces	4.69
do	Hard pebbly marl	2 47	5.39	12.46	28 32	27.90	traces	52.28
315 to 316	Sandy limestone	1.02	2.22	21.62	49 13	35.16	traces	30.81
321 to 322	Firm limestone	0.95	2.07	25.42	57.77	39.23	traces	25.94
323	Sandy limestone	1.05	2.29	18.00	40.91	27.84	traces	45.80

*Undetermined. **Including phosphatic nodules.

The interest of these phosphatic occurrences lies, of course, in their bearing on the mode of formation of the main superficial deposits, which are the only ones yet discovered of extent or value.

ORIGIN AND MODE OF FORMATION OF THE PHOSPHATE BEDS.

It is apart from the purpose of this paper, even if its limits permitted, to discuss the various interesting theories that have been propounded by distinguished scientists in explanation of the origin and mode of formation of the phosphate beds.

With the large uncertainty always accompanying speculations of this character, also, it would be the height of rashness to assert any one of them as absolutely true and to reject the others, and the writer has no such purpose.

It may be of interest, however, to make a short presentation of what seems to him to have been the probable course of events, or rather the one appearing to agree most closely with the following more important facts of the case, as they present themselves.

The internal structure of the nodules and the fossils embedded therein, as distinguished from those merely intermingled with them, are identical with those of the Eocene marl.

In the land deposits, in the strata composed of the phosphatic nodules, the sands and clays or argillaceous marls, and main marl bed beneath them, the content of phosphoric acid has been shown to diminish from the top downward.

In the river deposits, the clays, etc., between the rock and marl are absent, and in some of them, like those of Coosaw and Bull Rivers, the marl has only a very small content of phosphate of lime, while that under Stono River, on the other hand, is like the land deposits in this particular.

While, as has been stated, the presence of phosphatic material has been shown at great depths under the surface, the indications are that such deposits or layers are of very slight extent, as, indeed, would be expected from the comparatively small amounts of phosphoric acid occurring in the marl at those depths.

The factors necessary for the formation of phosphatic nodules or lumps are a material containing phosphate of lime, usually and probably a marl or limestone with a greater or less content of phosphoric acid, and an abundant supply of water, carrying in solution carbonic acid gas, to act as a solvent and carrier of the carbonate and phosphate of lime. Both of these factors are, and doubtless always were, abundantly present in the Charleston basin. The marls under the land deposits always contain from 5 to 9 or 10 per cent. of phosphate of lime near the surface, and a persistent though gradually diminishing quantity as the depth increases, derived, probably, from the vast number of great fishes that swarmed in the Eocene ocean.

The solvent powers of water containing free carbonic acid, when acting on carbonate or phosphate of lime, are well known. While this action is very much increased, at higher pressures, on account of the larger amount of carbonic acid gas absorbed under such conditions, it has been shown by Bischof that, even at the ordinary atmospheric pressure, the surface waters of the earth contain five times as much carbonic acid as is necessary to hold in solution their normal contents of lime, and have therefore an ample excess to permit a considerable solvent action both on carbonate and phosphate of lime. The action of such waters, also, on phosphate of lime, while very much less than on the carbonate, is very much increased by the presence of chloride of sodium (common salt), a salt which is not only an important constituent of sea water, but one of frequent occurrence in surface waters in

general.

In a conspicuous degree are the requirements of the case met by the subterranean waters of the Charleston basin.

At all depths, from the 1,970 feet of the new artesian well and the 1,260 feet of the Wentworth Street well to the numerous 300 to 400 foot wells that dot the vicinity of Charleston, there are present, besides considerable amounts of bicarbonates and chlorides, important quantities of free carbonic acid gas in solution. The superficial soil waters also, in swampy localities, carry in solution notable amounts of organic acids derived from the decomposition of the residues of the more or less abundant, not to say luxuriant vegetation.

It seems probable that the upper portions of the comparatively soft marl, weakened doubtless by the perforations of marine boring animals, were torn away from the parent bed by various natural agencies, chiefly, no doubt, by the tidal action of the Eocene ocean, and broken into fragments of various shapes and sizes which were ultimately subjected to the action of the solvent waters.

The continued action of these waters removed from the marl fragments the greater part of their carbonate of lime, together with a much smaller proportion of their phosphate, leaving behind the bulk of the phosphate, the insoluble matter of the original mass and varying amounts of carbonate. As the waters became saturated with the dissolved phosphate, it is probable that diminutions of temperature or pressure, assisted by the well known tendency of phosphate of lime to concentrate, caused a deposition thereof in the residual masses, replacing to a greater or less extent the carbonate that had been lost. It is also practically certain that subterranean waters, which on escaping to the surface could not retain all the phosphate taken up at the higher pressures of lower depths, were of material assistance in the process of phosphatization. The perforation of the fragments, by offering a greater surface to the solvent, no doubt greatly facilitated its action.

The nodules were not formed in the positions in which they are now found, else they would probably lie directly on the parent marl. After formation, they were caught up and transported by the agency of the enormous tides of the Post-Pleiocene seas and deposited in valleys, hollows or old waterways, in which the marl bed had been covered by the clays and sands of a subsequent age.

It seems almost certain that, this transportation having been effected and the nodules collected in their final resting places, a secondary action took place; that phosphate of lime in solution in soil waters was deposited therefrom and, penetrating only the outer portions of the nodules, increased the phosphatic content of those parts.

It is true that the same enrichment could have been produced by a more energetic action of the solvent waters on the outer portions of the nodules and that the cores, or interior portions, having been less exposed to such action, would have had a smaller proportion of their carbonate of lime replaced by phosphate, and doubtless this cause did operate to some extent.

The enrichment of the phosphoric acid content of the upper part of the deposits, however, and more especially the cementation of the nodules into continous sheets, could only have been the result of some secondary phosphatization, which must have taken place after the final location had been effected.

To this or some similar anterior action are possibly due the phosphoric acid of the strata between the phosphate beds and the marl and the increased percentage of the same constituent in the upper portion of the marl bed, to which attention has been called.

It may be well to notice the fact that the source of the phosphoric acid of the nodules has been sought elsewhere than in the phosphatic Eocene marls, notably in the accumulated remains of animal life, on account of the large number of fossil bones and teeth intermingled with the nodules, though not incorporated with them.

To the general consideration that, where there is an immediate and obvious source of supply, it is scarcely necessary to seek for one that is remote, must be added the very striking fact that these very fossil bones have been preserved because they themselves have undergone enrichment by phosphatization and, instead of having been the source of the enriching agent, have been subjected to its action.

The absence, in Coosaw and other rivers, of the beds of clay and similar material found between the rock and marl of the land deposits might seem to indicate a formation *in situ*. But the practical absence of phosphoric acid in the marl beneath, and the occurrence of lumps consisting partly of rock and partly of unaltered marl, containing over 10 per cent. of phosphate of lime show that this was not the case, but that the material was washed down from the place of formation.

The highly polished nodules, sometimes observed, owe their lustre, no doubt, to the great attrition of the original transportation, enhanced, possibly, by the hardening effects of the secondary phosphatization.

To what the usually darker color of the river rock is due, it is impossible to state with certainty. The conditions of deposit in the double seam at Bolton mines, where the rock of the upper stratum appears to be identical with that found in Stono River, near-by, might be taken to indicate that, in some cases at least, the river deposits were formed after the land deposits, and it is possible, that having been subjected, under changed conditions, to the action of waters more highly charged with vegetable matter, they derived their deeper color from a larger deposition of carbonaceous material, a substance which, in point of fact, is generally found in greater quantity in river rock than in that from the land deposits.

IS THE PHOSPHATIZATION PROCESS STILL GOING ON?

The factors necessary for the formation of phosphate rock, pointed out above, being still present in the swamps and waters of the state, though to a much smaller extent, of course, than at the time of the main deposition of the beds, and probably having always been so, it is a natural assumption that the process of phosphatization has been more or less continuous to the present day.

From the nature of the case, however, it has been difficult to secure conclusive evidence of the recent continuance of this growth, as it has been called.

Specimen lumps consisting partly of unaltered marl and partly of phosphate rock, and other lumps appearing to occupy a position between the two have been cited in evidence, but appearing to be susceptible of possible explanation on other grounds, they can scarcely be regarded as conclusive.

Various objects, also, of human manufacture, found in the bed, with small adhering masses of phosphate, have also lacked conclusiveness, the articles not being imbedded in the phosphate, so far as the writer has been able to learn, and the adhesive process having possibly and probably been merely one of cementation.

Especial interest, therefore, attaches to a specimen dredged, in February last (1904), from the bed of Stono River, opposite

Bolton Mines, by Dredge No. 1, Captain John May, of the Stono Mining Company.

The article in question, which lay under eight feet of sand, is an iron hook about five inches long, in a fine state of preservation, though of course highly oxidized, around the shank of which is a continuous ring of phosphate rock.

IRON HOOK WITH RING OF PHOSPHATE ROCK.

Both the hook and the phosphatic mass surrounding it are clearly shown in the accompanying photographic reproduction.

It would appear that falling overboard from some vessel, or perhaps forming part of some anchor chain, the hook penetrated the soft marl, which was subsequently phosphatized, with the result shown.

To avoid the unavoidable risk of injuring the specimen, only a small fragment has been removed, sufficient to verify its phosphatic character, but not for quantitative determination.

PHOSPHORIC ACID AND PHOSPHATE OF LIME.

While the general question of manures, particularly in respect to the use and importance of their several constituent elements of plant food, manifestly lies without the scope of this article, it seems desirable to point out two facts which give pre-eminent importance to phosphatic manures and, therefore, to the raw materials of their manufacture.

These facts are, first, the comparatively scanty occurrence and more or less unavailable condition of phosphoric acid in the soil; and, second, and the more important of the two, that, unlike the more costly nitrogen, it cannot be derived with greater or less facility from the atmosphere, but that its removal from the soil can be compensated only by the addition of more or less expensive phosphatic manures.

While in this last respect it resembles potash, a much smaller addition of the latter is usually required for crop nutrition, and its role is consequently less conspicuous.

The history of phosphoric acid is remarkable for its comparatively modern character and recent development; and this in spite of the fact that its principle elementary constituent was separated from its salts and recognized almost a century and a half before its own nature was discovered, and still longer before its general occurrence and great importance in the economy of nature were made manifest.

It was not until about the year 1669, that Brand, a bankrupt Hamburg merchant, while searching for the philosopher's stone, separated from human urine a substance to which, from its striking property of luminosity in darkness, he gave the name of phosphorus, "light bringer."

Though the remarkable properties of the newly discovered substance naturally attracted great attention among the scientists of the day, its method of separation remained a secret until it was rediscovered by Kunkel, of Rendsberg, whom Meyn (in his valuable monograph on natural phosphates, which has been freely followed in this connection), describes as the "first great, really practically chemist."

In 1688, nineteen years later, phosphorus was found in mustard seed by Albinus, and its presence thus shown in vegetable life as well as in the animal organism.

The backward condition of chemical knowledge and experimental processes probably accounts for the fact that, while the new substance continued to attract great interest as a sort of scientific toy, its discovery remained otherwise barren of results.

As phosphorus, on exposure to air, is converted by oxidation into phosphoric acid, escaping under the form of dense white fumes, the discovery of the latter was necessarily coincident with that of the former.

The relationship between the two, however, does not seem to have suggested itself, the fumes being supposed to consist of a mixture of vitroil and muriatic acid.

This decidedly hazy view subsisted until 1743, when the true nature of the presumed mixture was discovered and phosphoric acid was identified as such.

A quarter of a century later the next great step towards modern manuring was made by Gahn, a Swede, in his discovery of the occurrence of phosphoric acid in bones, and its subsequent recognition as a common and indispensable constituent of all more highly organized animal life.

About 1780, Gahn discovered the presence of phosphoric acid in the mineral kingdom in a specimen of phosphate of lead, and shortly afterwards Klaproth and Vanquelin showed several different varieties of apatite to be composed of the same phosphate of lime as that which forms the earthy constituent of bones.

"These," says Meyn," are the plain but significant commencements of the chemical discoveries as to the presence of phosphorus in animals, plants and minerals. None of the disinterested naturalists to whom we are indebted therefor anticipated, or could then anticipate, how boundlessly important these facts were to prove to their successors for the comprehension of nature." He might well have added "and to mankind at large for its welfare and preservation."

When the nineteenth century dawned, no great progress had been made in the development of phosphatic manures. Although the use of bones as manures had been begun about the middle of the previous century and had been continually increasing, their fertilizing value was ascribed to other constituents than the phosphate of lime, to the gelatine and grease.

Th. DeSaussure, in 1804, again called attention to the presence of phosphate of lime in animals, and to the fact that no one doubted that this salt was an essential constituent of bones. He also announced that he had found the same salt in the ashes of all vegetables he had examined therefor, and was of opinion that there was no reason for supposing that they could exist without it.

The use of bones increased very rapidly, especially in England. To such an extent was this the case that, in 1822, more than 33,000 tons derived, it is said, "mostly from the battle-fields of the late wars," were imported into that country from Germany alone. So great was the demand that even catacombs, it is stated, were robbed to meet it. In 1859, the importation into Great Britian had become 84,820 tons.

In the meanwhile the accumulation of analytical evidence was bringing about the conviction that the invariable presence of

various salts in the ashes of plants was more than accidental, and that they were necessary to a proper development of the organism.

When Justus Von Liebig showed this in 1840, and recommended the use of sulphuric acid as a solvent for the phosphate of lime in bones, to render it available for plant food, the final step was taken to the introduction of the present system of artificial manures.

DISCOVERY AND USE OF MINERAL PHOSPHATES.

In 1818 Berthier had shown the presence of phosphate of lime in nodular form at several localities in France, a discovery soon followed by similar ones in England.

The successful application of sulphuric acid to bones at once suggested the possible utilization of these mineral phosphates by the same process.

The first mixture of this kind was made, in 1841, by a Mr. Fleming, of Barrochan, England, who used English coprolites, mixing them with acid on his barn floor.

Experiments with material made in this way were so successful that its use grew rapidly and the fertilizer industry, as now known, was inaugurated by the erection of a factory for its manufacture by J. B. Lawes, afterward knighted for his great and invaluable services to humanity as an agricultural investigator.

THE FIRST STEPS IN SOUTH CAROLINA.

In South Carolina, in the meanwhile, the need of fertilizers had made itself felt, and steps had been taken towards meeting it.

In 1842, the services of Edmund Ruffin, a native of Virginia, were secured for an agricultural survey of the State, and his report, made in 1843, was devoted chiefly to its marl and limestone deposits. These he describes at great length, but, as regards their composition, confines himself to stating the percentages of carbonate of lime, in his opinion the only constituent of any agricultural value.

In his examination of the Ashley River marls the phosphatic strata did not escape his observation, for in his description of these beds he mentions "lumps of stony hardness, full of impressions of shells, found in great quantity in the neighborhood," a few feet above the marl, that contained 6 per cent. of carbonate of lime.

The stony lumps were undoubtedly phosphate nodules, the Brisbane place alluded to by Mr. Ruffin ("J. S. Brisbane's landing, nine miles above Charleston,") having been either just above or below Bee's Ferry, the property in question extending at that time on both sides of the ferry, on the eastern bank of the Ashley.

Edmund Ruffin.

Resigning at the end of the year, Mr. Ruffin was succeeded by Professor M. Tuomey. A part of the latter's report, dated November, 1846, is devoted to the calcareous manures of the State, but, besides giving the quantities of carbonate of lime in the various marls, he calls attention to the presence of phosphate of lime therein, the discovery of which he credits to Professor C. U. Shepard, Sr., and to Doctor J. Lawrence Smith, a pupil of Professor Shepard.

He presents detailed analyses of the Ashley River marls, made by Professor Shepard, in all of which the presence of the phosphate of lime is shown.

In describing the Ashley beds Professor Tuomey says, (p. 164):

"In ascending the Ashley, from Charleston, marl is first seen at Bee's Ferry, on both sides of the river, below high water level. Both here and elsewhere, on the river, it is exceedingly uniform in structure and internal appearance, with the exception of about two or three feet of the surface, which is composed

of irregular and waterworn fragments of marl stone, embedded in clay, and containing numerous fossils, in the state of casts. These fragments are scattered over the surface, so as, in some places, to offer obstruction to the cultivation of the land. On the Rev. Dr. Hanckel's plantation I had good opportunity of examining these fragments; and at Drayton Hall they have been gathered from the lawn and thrown into heaps."

Professor Tuomey goes on to state that, though at first disposed to refer these fragments to a different formation from the underlying marl, he had found that nearly all the fossils were common to both, and concluded that the fragments were only the surface of the marl torn up and scattered. He concluded, also, that the dispersion of the fragments was of comparatively recent occurrence, and was probably due to the recession of the waters of the ocean at the time of the elevation of the Post Pleiocene to its present level.

He says in continuation; "I have more than once alluded to the removal, by solution, from calcareous rocks, of a portion or all of the lime. This has taken place, to a great extent, in the beds under consideration. In many instances there is little more left than the silica and alumina of the marl, with a trace of lime; and the latter ingredient rarely exceeds 6 per cent."

In making this statement Professor Tuomey doubtless had in mind the marl analyses of Ruffin, which he quotes further on in his report, particularly that of the "lumps of stony hardness," previously alluded to in the present article, when speaking of Ruffin's work. By the term "lime," also, he doubtless meant carbonate of lime.

Tuomey evidently did not suspect the presence of phosphoric acid in the lumps in question, doubtless misled by the fact that, while he was aware that the agricultural value of the marls was enhanced by the presence of the phosphate of lime which had been shown to exist therein, he was of opinion that the phosphate was of small value when compared with the carbonate. For he says specifically: "I apprehend that the carbonate of lime will always prove the constitutent of greatest importance, valuable as the phosphates are." (p. 235.) He could have been led to this opinion only by the great preponderance of the carbonate, for in the appendix to his report he publishes several analyses of marl made by Professor Shepard, in which the latter gives the amounts of phosphate of lime present in the samples examined and then makes the following comments. (Tuomey's Report, page xxxvii):

"Prior to these analyses, it was very difficult to account, in any very satisfactory manner, for the known efficacy of such marls in agriculture; since the soils on which several of them had been employed were known, by analysis, to be no more deficient in carbonate of lime and magnesia than the prolific soils of the Mississipi Valley."

"The reason assigned for marling in South Carolina, by Mr. Ruffin, viz: that carbonate of lime is thereby afforded to land, does not appear to me to be the chief motive the planter has for following up this practice. * * * while the phosphate of lime and magnesia is that constituent which, in my opinion, is decidedly paramount to all others."

It would seem that so clear and striking an announcement would have proved fruitful in suggestion and that, when in spite of the great differences in appearance and other physical characteristics between the nodules and the subjacent marl, as well as the distinct segregation of the former from the latter, Tuomey had been led to the abandonment of his first views, and to the conclusion that the nodules were but detached and altered fragments of marl, attention would have been closely directed to them, and an investigation made to determine more accurately the nature of a material that had undergone such a notable alteration.

That such was not the case is made more remarkable by the number and character of the investigators. The probable explanation is found in the general limitations of geological surveys.

In surveys of this character, and where a large amount of territory has to be covered, the work involved is invariably greater than the means for carrying it on, necessitating economy of every kind and in every possible direction.

The aim of the geologist is to examine and determine, as far as is possible, the structural character of the region in which he is operating, and it being manifestly impossible for him to examine every fragment he meets with, and as the character of such fragmentary material is apt to show differences from that of the parent bed, having been more or less altered by exposure to air and weather, it is the practice to draw all samples from the bed proper to insure arriving at the real character of the formation in general.

At the time of these explorations, also, the knowledge of phosphatic materials was comparatively recent and extremely

limited, while its analytical determination, to-day still a matter of experienced skill, was then involved in many difficulties.

In addition, the utilization of amorphous phosphatic rocks in Europe was so recent, that it is doubtful whether they had yet come to the knowledge of those engaged in work at so distant a point as South Carolina.

These considerations explain and justify the failure to bring to light, at that time, the true nature of the phosphatic nodules.

To show that the course thus taken by events was in no way exceptional, two very conspicuous instances of similar occurrences, at a recent date, may prove of interest.

Shortly before the discovery of the hard rock deposits of Florida, an expedition, expressly equipped for the purpose, ascended the Withlacoochee River in search of phosphate rock.

This river is crossed by several limestone dykes, either only slightly below the surface of the water or projecting above it. Samples taken from these dykes were carefully tested and the absence of the desired material ascertained.

In every case, or nearly so, there were lying immediately alongside the dykes numerous lumps and even boulders of phosphate rock of very high grade, but appearing to be merely fragments detached from the main mass, no attention was paid to them and they escaped testing and discovery.

Still more conspicuous is the fact that the heavy and extensive beds of the Tennessee deposits, from a similar cause, entirely escaped the observation of a systematic geological survey, conducted at a much later date, when the character and value of such material were well known to all geologists; whereas, in Tuomey's day, as has been pointed out, the value of amorphous phosphates had been discovered only a couple of years, the artificial fertilizer industry was in its early infancy, and there was probably no knowledge of these far-reaching changes to give an impetus to the search for suitable phosphatic material.

THE DISCOVERY OF THE PHOSPHATES.

In an address delivered before the Medical Association of South Carolina in 1859, Professor Shepard, after describing various foreign stone phosphates that he had examined and urging a careful investigation of the marl beds, with the view of determining which contained the largest amount of phosphate of lime, struck a prophetic note when he stated that he sincerely entertained "the opinion that, as the supply of guanos from

abroad fails, we shall be looked to fill the vacuum their disappearance will occasion; and it would not be strange if a few years hence Charleston, besides supplying her own State, should ship more casks of phosphatic stone to the North than she now receives of ordinary lime from that region."

Professor Charles U. Shepard, Sr.

Though Professor Shepard failed to so specify in his address, it seems evident from several considerations that in using the term "phosphatic stone" he had in mind material other than marl rich in phsophoric acid. As stated by himself, in the same lecture, he had just been engaged in so careful an investigation of several foreign rock phosphates, that he had succeeded in identifying two new mineral species, one of which he had found to contain 80 per cent. of phosphate of lime.

To the keenly analytical and acute mind of this distinguished mineralogist it must have been evident at a glance that no mere phosphatic marl could ever be "exported to the North" in competition with phosphates of the sorts that he had recently had under examination, or be expected to supply their places.

Indeed it was just about this time that he pointed out the Ashley River marls and rocks as a source of phosphoric acid, in connection with what was perhaps the first fertilizer plant established in the State, under the auspices of Col. Lewis M. Hatch, of Charleston.

Colonel Hatch, in a letter to the Rural Carolinian, (Vol. II, page 357), gives an extremely interesting account of this enterprise, from which the following extracts are taken:

"In the autumn of 1859 my brother-in-law, Mr. T. P. Allen, proposed that we, together with my son, Melvin P. Hatch, then in Europe, should utilize the refuse matter of Charleston for fertilizers. I had been selling Columbian guano; and, for security to my customers, had engaged Professor C. U. Shepard to examine each cargo as it arrived. We called Professor Shepard to our consultation, and determined to prosecute the new work with Professor S. as our chemist."

"We used mainly bones, charcoal, ammoniacal liquors, ashes, refuse from soap boilers, burnt rice, sulphuric acid and Peruvian guano, making a fertilizer which we thought worth thirty dollars a ton, and sold for that price. It was in every way a success.

"We gathered enough bones to have lasted us perhaps, with increased business, another year; but seeing that the supply of phosphates would be short from this source, Professor Shepard advised that we should look to the Ashley River marl or rocks for a supply, saying 'he felt sure that these would prove to be richer in phosphates than was usually supposed.' No sooner proposed than acted upon. In the spring of 1860 we went to Major Vardell's place, finding the rock there and elsewhere along our route."

"Subsequently making up my mind that the best place from which to obtain supplies was Gen. Brisbane's plantation, now the site of the Wando Works, I caused to be gathered there a quantity of the rock or nodules, which I sent to Prof. Shepard at New Haven. I did this to make sure that the material at this place was of such quality as would suit our purposes and make the purchase of the land safe. When I met Prof. Shepard, in the autumn of 1860, he said in reply to my inquiry as to quality:

"'I found it richer far than I expected; so rich, that with it we can drive all other fertilizers out of the market, and may invade foreign markets."

The samples shipped to New Haven were powdered and applied to Professor Shepard's garden, yielding results which helped him to form the high estimate of value expressed to Colonel Hatch.

Unfortunately, not having spent the summer in New Haven, and thus being away from his laboratory, he made no analysis of the ground nodules.

Why, in the absence of such an analysis, he was so strongly impressed with the idea that their content of phosphate of lime was so much higher than usual, is not known, though it is extremely probable that it was largely due to physical resemblances to some of the foreign phosphates he had examined not long before.

Professor Shepard was a mineralogist of high reputation, and possessed to such a remarkable and exceptional degree the power of detecting the minute differences in physical characteristics that distinguish many minerals, that it seemed rather intuition than conscious discrimination, and it is, therefore, very probable that the suggestion made above is true.

Not only to Colonel Hatch did Professor Shepard give the advice to seek phosphatic material in the nodules of the Ashley beds, as is shown by the following extract from a letter dated July 11, 1873, addressed by Geo. T. Jackson, Esq., of Augusta, Georgia, to Professor Charles U. Shepard, Jr.

"In 1860 your father and myself entered into an agreement to manufacture a fertilizer at this place and, under his direction, I secured a location and at once proceeded to gather material. I had purchased all the raw bone to be had here and other material and had gathered sufficient to make a fair start.

"The supply of bones, however, we early saw would not be sufficient and, in looking about for a substitute, he told me that there was a large deposit of marl on the Ashley River which he thought would answer our purposes.

"At my request he sent me some specimens of the identical phosphate now being used so advantageously in the manufacture of fertilizers. These specimens I retained for two or three years. This was in the spring of 1861. Owing to the war our operations were suspended and consequently we were not able to reap the advantages that I have no doubt we should have."

The same cause, the outbreak of the war, put a stop to the operations of Colonel Hatch, who, believing after the war that the people of the South were too poor to buy fertilizers, decided to move to North Carolina.

He concludes the communication quoted from above as follows: "After I was committed here, I found to my surprise, on a visit to Charleston, that our people were buying fertilizers largely from the North.

"Consulting with Professor Shepard, (unable at the moment to take hold myself,) a partnership was formed between Major Vardell and Mr. Blake, of New Haven. Mr. B. was to furnish capital; and the firm proposed to use a quartz crusher, the invention of his father, for crushing the material. I sold them the materials already gathered,—land, buildings, steam engine, etc. Going South to spend a few days at Christmas, Mr. Blake was unfortunately drowned; and with his death that effort ended.

"During the war I mentioned to Mr. John R. Dukes that Professor Shepard had remarked to me, in relation to the Ashley River deposits: "That about nine miles from Charleston there was a deposit which reminded him very much of the Columbian guano," and from this sprung the search for these nodules which has resulted, through the agency of Doctors Ravenel and Pratt, in this valuable discovery. The truth is, that the first step was taken when Mr. Allen proposed to utilize the refuse matter of Charleston.

"Mr. Allen made the germinal suggestion. Professor Shepard, as chemist, pointed out the source of needful supply, and proved its value. He did this in advance of all others. In advance, please bear in mind, of Professor Ansted, whose book we did not need, even in 1864, to give us the thought. We were convinced in 1860, that, with the Ashley River phosphates, we could compete with the world in fertilizers.

"Let us give to Mr. Allen that which is his due, and to Professor Shepard his,—that as a scientific man he pointed out and predicted their future use."

Other parties now entered the field of fertilizer manufacture. In November 1866, Doctor St. Julien Ravenel, of Charleston, a man of very distinguished scientific attainments and an able chemist, associated himself with Messrs. W. C. Dukes & Co. and Mr. D. C. Ebaugh, for this purpose.

The factory established by Colonel Hatch and his associates had been located near the forks of the road. The new enterprise was started, early in 1867, on Palmetto wharf, on the city water front. The factory was provided with "a huge iron crusher which breaks the limestone and other hard substances into fragments, a pulverizer and a mixer," but, having no acid plant, had to bring its sulphuric acid from the north.

Meeting with the usual experience, a threatened dearth in the supply of bones, the company had recourse to Navassa phosphate rock, receiving the first consignment of four hundred and fifty-nine tons, on November 10, 1867. This shipment, to-

gether with some four hundred and fifty tons received thirteen days later, was never used, being ultimately shipped to Baltimore.

THE FINAL STEP.

The end, for which all these incidents had been but a long chain of preparation, was now near at hand.

The opportuness of its advent no man can question. The temporary reaction that followed, as is usually the case, the close of a devastating and disastrous war was rapidly losing its energy, and the outlook, particularly for the neighboring sea-coast country, was gloomy in the extreme.

Made up in large part, as it was, of swampy and undrained and unreclaimed lands, with most of the expensive improvements necessary to its peculiar crops falling to decay or entirely gone, its future seemed fraught with disaster and the outcome no man could foretell.

Doctor St. Julien Ravenel.

Some time in the summer of 1867 Doctor Ravenel's attention was directed to the nodular deposits of the vicinity. What gave it this direction is not authoritatively known, Doctor Ravenel, so far as the writer has been able to learn, never having published any statement of the matter.

Colonel Hatch thought and said that the information given by him to Mr. John R. Dukes during the war, quoted above, was

the cause of the search. While this is possible, it is extremely improbable. Had Doctor Ravenel had any information that there was even a remote possibility that he might be able to supply the needs of his company with a material so easily accessible, it seems hardly probable that he would have agreed, as must have been the case, to the purchase of at least so large an amount of Navassa rock. What is probably the true version of the matter is that given by the writer (anonymous) of an extremely valuable article on the subject of phosphates in "The Trade and Commerce of Charleston, "published by the Chamber of Commerce in 1873.

The statement therein contained is as follows:

"During the summer of 1867 Dr. St. Julien Ravenel received from Dr. F. M. Geddings specimens of teeth nodules and marl, taken from 'The Elms' plantation, Goose Creek, owned by his father, Dr. E. Geddings. While examining these specimens, Doctor Ravenel became aware of the true character of the nodules and through Mr. Theodore Stoney, made an effort to procure them from the banks of the Ashley River."

Whatever the inciting cause, Doctor Ravenel was soon satisfied by his investigations of the suitability of the nodules for the purposes of fertilizer manufacture, and doubtless had in mind their utilization in his works, for, in a foot note to the article from which the above extract is made, Mr. Stoney is quoted as saying: "Early in the summer of 1867, Dr. St. J. Ravenel informed me that he had been examining the nodules from Ashley River, and found them so valuable that he wished me to engage a competent person to collect and bring them to the city. I did engage Capt. Beese, who had run on the river all his life, to do so."

About this time Doctor N. A. Pratt came to Doctor Ravenel to confer with him in regard to an enterprise for which he had been laying the plans. Doctor Pratt, a native of Georgia, had visited Charleston on inspection tours during the war, and while there learned of the fact that the marls of the State contained from 10 to 15 per cent. of phosphate of lime. Struck by their superiority, in this respect, to those of his native state, which contain, on an average, some two and a half per cent. of this constituent, he secured specimens and forwarded them to his laboratory, with the purpose of analyzing them, a purpose however, which was never carried into effect.

Doctor Pratt states that during the war he formed a plan to erect chemical works at some point in the South. Being satis-

fied with the location of Charleston, he settled there after the war, and early in 1866 endeavored, without success, to secure the necessary capital to erect an acid plant and fertilizer works.

It is stated, that the object of his conference with Doctor Ravenel was to inquire of the latter, with whose high attainments and great knowledge of local conditions he was well acquainted, as to the feasibility of finding some use for the output of his proposed acid plant.

Doctor N. A. Pratt.

Doctor Ravenel in reply handed him one of the nodules, informed him of its value, and, according to one account, without mentioning any figures as to content of phosphate of lime, told him that the nodules, of which the one he was handing him was a sample, would yield a raw material requiring all the acid he would be able to make.

Doctor Pratt's account of this interview differs from the above. He stated that he went to Doctor Ravenel's office to look at some foreign guanos that had been received by the latter. While there, Doctor Ravenel showed him one of the nodules, telling him that it contained from 10 to 15 per cent. of phosphate of lime, and gave it to him for examination.

The two accounts differ materially in important points, but the differences were probably due to misconceptions on both sides. From the subject of foreign guanos to that of local acid-

making the transition was natural and short, and the importance of the latter to the manufacture in which both gentlemen were earnestly interested was so great, that it probably became the main subject of discussion, and the idea might readily have been engendered in the mind of Doctor Ravenel that this had been the object of Doctor Pratt's visit.

On the other hand, when the nodule was handed to Doctor Pratt there was doubtless some discussion of its occurrence in connection with the adjoining marl, and some remark made by Doctor Ravenel as to the phosphoric acid content of the latter might readily have been misunderstood by Doctor Pratt as having reference to the nodule, which was the immediate object of discussion. That this, or something similar, was probably the state of the case, is made almost certain by the consideration that Doctor Ravenel could scarcely have been ignorant of the value of the nodules. He had been long and prominently engaged in the scientific life of the neighborhood, had been familiar with the men who had studied and knew the facts connected with the subject, and in so small a circle could not possibly have escaped becoming more or less familiar therewith. Whether or not he had ever heard of Professor Shepard's estimate of the value of the nodules, the ones in question had been handed him for examination, and the mere fact that he selected one of them for Doctor Pratt is proof presumptive that he had some special reason for the segregation, especially when the insignificance of the phosphate stratum, as compared with the marl bed, is remembered. To the writer it seems certain, that Doctor Ravenel did not become acquainted with the value of the nodule until after the purchase of Navassa rock, alluded to above, had been made. It is impossible to believe that, if he had had even a remote idea of the possible availability of a material, the truth as to whose value it would be so easy to ascertain, he would have allowed his company to make the expensive purchase in question. It seems further certain that, subsequent to the Navassa purchase, he analyzed the nodules which had been placed in his hands and ascertained that they contained an amount of phosphate beyond that shown by any analysis previously made, and there can be no doubt that, such being the case, he was fairly entitled to the credit of an independent discovery of the value of the nodules.

The following letter, received since the preceding paragraphs were put in type, is of great interest, and strongly confirmatory of the views that have been set forth above.

Summerville, S. C., November 5, 1903.

My Dear Mr. Chazal: In connection with our recent conversation on the subject, I would state that I recall a visit paid my father by Dr. St. Julien Ravenel at the chemical laboratory of the Medical College of the State of South Carolina, in the winter of 1867-68, at which Dr. Ravenel imparted to him the results of his investigations as to the occurrence and value of the South Carolina phosphatic deposits, more particularly the nodular beds on the Ashley.

My father at that time expressed his surprise and gratification that some had been found which contained over sixty per cent. of bone phosphate of lime, whereas his own previous examinations had indicated less than fifty per cent., i. e., in the "forties."

I have every reason to believe that the conversation referred to was the first intimation that my father received of the renewal of the attention being paid to the local phosphatic beds, so happily inaugurated by Dr. Ravenel, and so diligently prosecuted by him and others.

Yours very truly,

CHARLES U. SHEPARD.

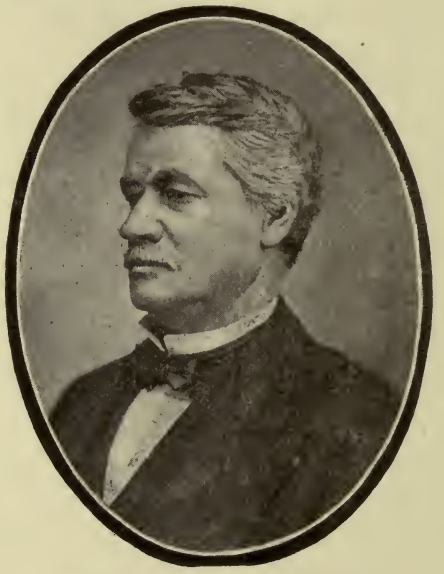
INAUGURATION OF THE PHOSPHATE INDUSTRY.

In any event, Doctor Pratt, on receiving the nodule from Doctor Ravenel, entered upon its analysis and found it to contain 34.40 per cent of phosphate of lime.

Appreciating at once the great interests at stake, he hastened to consult Professor Francis S. Holmes as to the occurrence of the nodular strata and the possible supply of nodules. To Professor Holmes they were old friends. He had made the pursuit of science, for the love thereof, his life work, had studied diligently the geological history and conditions of the low-country of South Carolina, had been intimately associated with Tuomey, with whom he had collaborated in valuable treatises on the Pleiocene and Post-Pleiocene fossils of the State, and in his extended investigations had acquired a thorough knowledge of the country immediately around Charleston.

Professor Holmes showed Doctor Pratt a large collection of the nodules and gave him some specimens, two of which yielded, on analysis, 55.92 per cent. and 55.52 per cent. bone phosphate of lime. Samples obtained by Doctor Pratt himself on his visits to the deposits, made in company with Professor Holmes, gave results varying from 57 to 67 per cent. of bone phosphate.

Doctor Pratt appreciated fully the importance of the information afforded by these analyses and by what he had learned from Professor Holmes as to the occurrence and quantity of the nodules. In company with the latter, he made an effort to secure in Charleston the funds necessary for a proper development of the enterprise. Failing to do this, they proceeded to Philadelphia, where their efforts were effective and resulted in the formation of the Charleston, S. C., Mining and Manufacturing Company, which was formally organized at Charleston on November 29, 1867, with a paid up capital of one million dollars, Professor Holmes being elected president, and Doctor Pratt, chemist and superintendent.



Professor Francis S. Holmes.

The new company speedily secured for itself a large area of phosphate lands on both sides of the Ashley River, about Bee's Ferry and Ten Mile Hill.

The intimate knowledge of local geological conditions possessed by Professor Holmes was of infinite value in this work, and the territory secured at that time, together with other lands purchased at a later period, formed a phosphate property which could not be duplicated, which was extremely valuable on account of the quantity and quality of the deposit, and which was in immediate proximity to navigation.

In the meanwhile, Doctor Ravenel and his associates, organized as the Wando Fertilizer Company and acting indepen-

dently and, it is said, without any knowledge of the efforts being made in Philadelphia, proceeded to gather a supply of the nodules from their Bee's Ferry property and utilized them in their fertilizer manufacture during the following winter, shipping their Navassa rock, as has already been stated, to Baltimore.

Relying entirely, as they did, on local capital, their efforts were very much restricted; they were prevented from making any attempts to secure a large acreage of phosphate property, and looked mainly to securing a supply for their own use, as manufacturers.

The formation of these two companies not only marked the inauguration of the new industry in both its branches, mining and manufacturing, but it was also the last step in the work begun long since, even though unconsciously, by Ruffin and Tuomey, and carried along, added to and completed by their successors.

Delayed in its first stages by the slow spread of knowledge of the new ideas in manuring, it had met, when apparently on the verge of completion, with a serious check, in the breaking out of the civil war, a war so all-absorbing and, in Charleston at least, so ruinous in its consequences of destruction of property and paralysis of trade and activities, that the only matter for surprise is that the end was arrived at so soon.

DEVELOPMENT OF THE DEPOSITS.

On December 4, 1867, Messrs. Dukes & Co., the agents of the Wando Company, shipped the first small sample lot of rock to George E. White, of New York; on the 16th of the same month the Charleston Mining Company made its first shipment, also a sample lot of sixteen tierces, by the steamer Falcon, to Baltimore, whence it was forwarded to Philadelphia, where a part of it was made into super-phosphate by Messrs. Potts & Klett.

The first cargo, of 100 tons, was shipped by the schooner Renshaw to Baltimore, on April 14, 1868, by the Wando Company. Eight days later, on April 22, the schooners T. G. Smith and Anna Barton sailed for Philadelphia, carrying the first cargoes of the Charleston Mining Company, of 296 and 329 tons respectively, loaded at Lamb's.

So far, no mechanical washers had been devised or erected, and the only cleansing received by the rock comprising these two shipments was such as could be given by a rough scrubbing

with hand brushes in a convenient creek. It is not surprising, then, to learn that the cargoes were so dirty that they had practically to be mined out of the vessels.

The price fixed in this first contract was fourteen dollars per ton, netting about ten dollars per ton, f. o. b. In spite, however, of the small preparation given to the rock, this price was not found remunerative and the contract was cancelled.

The cause of this lay chiefly in the way the rock was mined, consisting, as it did, in digging a series of separate small pits, the labor being greatly increased, the yield small, and the output per acre greatly reduced by the amount of ground left undug. On these very properties of the Charleston Mining Company, some of the fields that had been pitted in this way were afterwards mined systematically, and as much rock taken from them as had been obtained at the first digging.

These were, of course, the usual troubles of a new mining industry, and were soon overcome.

The first washer built by the Charleston Mining Company, the Washer No. 1, was given practically no elevation above the ground, and all the material had to be rolled up on the rock-piles in barrows. The costliness of this handling was soon realized, and the No. 2 Washer, erected in 1869, was considerably elevated. During the year 1868 the shipments of this company amounted to 4,403 tons, all of which went to Philadelphia. Until the latter part of 1879 all of their rock was shipped in a washed, undried condition. After that time, however, a portion of the product was dried in bins with hot air, until 1882, when the bins were abandoned and the present system of kiln burning over wood was adopted.

FAVORABLE RECEPTION OF THE NEW ROCK.

The new material caused great excitement in the fertilizer world. A part of the first sample shipment to Philadelphia was forwarded to Messrs. Coates & Co., of London, and distributed by them for examination and, in a letter from them, it was stated, that "it had been analyzed by distinguished chemists of England, France, Prussia, Austria, Denmark, Sweden and Switzerland, and a high opinion of its value held by them."

Unfortunately for the land phosphate industry, more or less negligence in preparation and carelessness in shipment were the rule for several years, whereas the opposite was the case with its river rival.

The latter rock, too, generally contained, naturally, a smaller amount of oxide of iron and alumina, the difference between the two classes of rock in this respect, however, being greatly increased by the respective methods of preparation.

The amount of these two constituents in a rock having a potent influence on the solubility in water of the super-phosphate produced from it, this point was one of great importance in countries, like England, where no value was assigned to any other form of phosphoric acid than the water soluble.

These points produced a strong prejudice against the land rock, which prevailed for many years, during which it was practically excluded from the European market and its activities limited to the domestic field.

THE RIVER DEPOSITS.

On March 1, 1870, the General Assembly of the State, by a vote of more than three to one, passed over the veto of Governor R. K. Scott, the act giving the Marine and River Phosphate Mining and Manufacturing Company "the right to dig, mine and remove for the full term of twenty-one years, from the beds of the navigable streams and waters within the jurisdiction of the State, the phosphate rocks and the phosphatic deposits," subject of course, to riparian rights and freedom of navigation.

The terms of the Act were extremely liberal, the only requirements by the State being that the company should file a bond of $50,000, to secure the making of true returns of the amount of rock mined, and pay a royalty of one dollar per ton. No conditions were imposed in reference to a thorough and systematic mining of the deposits, and apparently the only changes made by the General Assembly in the bill presented to it was the striking out of the word "exclusive", in describing the character of the rights granted.

The absence of knowledge as to the extent and character of the deposits, and the varying conditions of quantity, quality and accessibility prevalent therein, would, it is true, have made a rational handling of the question one of great difficulty even for an honest and intelligent body. The General Assembly that had the settlement of the matter possessed neither of these qualifications, but was distinctly and notoriously ignorant and purchasable, a large number of its members being unable to read or write.

Governor Scott's veto, ostensibly at any rate, was largely based on the idea that the corporators, for the most part owners of

land deposits, would fail to operate the river territory to any extent, if at all, to prevent competition with their land mines.

He professed to fear that, although the word "exclusive" had been stricken out in the Senate, such rights had been given, either really or practically, and that private citizens would be deprived of the privilege of mining.

Supposing the deposits to be of practically unlimited extent, their proper utilization and development, if the question ever suggested itself to him, doubtless seemed a matter of comparatively small moment.

Experience has demonstrated that the true policy of the State, at that time, was to have had the territory properly examined and subdivided, and to have sold exclusive rights to mine in the various subdivisions to responsible individuals or companies, the mining to be subject to the supervision of the authorities and royalty to be paid on the output.

This, or some similar course, would have prevented the deterioration and partial ruin of some of the deposits that followed, in consequence of the mining of only the more easily accessible portions of the beds.

The State, however, failed to see the wisdom of this course, and for the most part, then and afterward, acted on the fallacious idea that, instead of being the property of the people of the State as a whole and as such to be worked in the way to obtain the largest returns, the phosphate beds were the property of the people as individuals, to be a source of profit to them as such, this being, of course, particularly applicable to the residents in the vicinity of the beds.

The only special right the latter should have enjoyed was the opportunity of employment afforded them by the development of the new industry, but the exploitation of the general rights system offered too fertile a field to political demagogues to be overlooked, especially when the other citizens of the State failed to realize the state of affairs and to take steps to preserve their rights, which were thus trespassed upon. It is true that no good could have been accomplished in this respect during the existence of the carpet-bag regime, but even after its overthrow in 1876, when the exclusive rights system was recommended by Attorney General Conner and afterward by Special Assistant E. L. Roche, no change was made and the old system was adhered to.

Fortunately for the interests of the State, the profitable handling of the river beds to any extent demanded the installation of

large and expensive plants for the excavation and treatment of the rock, and the large investments required necessitated more or less thorough exploitation.

THE MARINE AND RIVER MINING COMPANY.

This company, organized March 15, 1870, with a capital of $500,000, half of which was paid in, commenced operations the following June, and raised and shipped about 3,000 tons by the end of the same year.

In the meanwhile, Professor Charles U. Shepard, Jr. had been employed by the company to examine the river territory, with the exception of Coosaw River and North Wimbee Creek, and as the result of his investigations reported that, although there were large beds of rock in Stono and other rivers, their character was such as to require great care and prudence in mining to make the new enterprise profitable, and that he did not consider the outlook for large returns as favorable.

Prior to this, the Marine and River Company, which in spite of the excision of the word "exclusive" from its act of incorporation, claimed to have received exclusive rights to mine in all the navigable waters of the State, had transferred these rights in Coosaw River to the Coosaw Mining Company, and in North and South Wimbee creeks to the South Carolina Phosphate Company (Limited), generally known as the Oak Point Mines Company.

The General Assembly, however, disregarding the claims of the Marine and River Company, proceeded to grant other licenses to mine, the result of which was a suit brought in the United States Circuit Court, in 1874, by William L. Bradley, of Massachusetts, a large stockholder in the Marine and River Company, against the South Carolina Phosphate and Phosphatic River Mining Company, in which the Court decided that no exclusive grant had been made to the Marine and River Company. No appeal was made from this decision, which was thus, apparently, accepted.

THE COOSAW MINING COMPANY.

The Coosaw Mining Company commenced operations in November, 1870, locating its works on Chisolm's Island, on Coosaw River. The royalty due by it on the rock mined was paid, at first, through the Marine and River Company, but later on, in 1878, it was paid directly to the State, the Company having filed a bond for $50,000.

The decision of the United States Court in the Bradley case, referred to above, necessarily involved the validity of the rights that the Coosaw Company was exercising under its grant from the Marine and River Company, but in 1876 an act was passed, nominally to settle the periods at which returns should be made and royalty paid, by which, however, "its right to dig and mine in the navigable waters of the State" was recognized, and it was granted "the exclusive right to occupy, dig, mine and remove phosphate rock and phosphatic deposits from all that part of Coosaw River lying opposite to and south of Chisolm's Island, whereon their works are located, and to the marshes thereof."

THE OAK POINT MINES COMPANY.

The Oak Point Mines Company, an English corporation organized in 1870, and which had purchased a body of land deposits on North and South Wimbee creeks, known as Kean's Neck, engaged in both land and river mining.

It received, as has been mentioned, a grant from the Marine and River Company to mine in the neighboring streams, but having raised the claim that North Wimbee Creek was not a navigable stream, that, therefore, the riparian rights of the company extended to the middle of the stream and that the rock mined therefrom was not subject to royalty, and no royalty having been paid in 1873 and 1874, the question was carried into the courts by the State and a decision obtained adverse to the claims of the company.

The Act of 1876, by which the Coosaw Company had benefited, conferred on all other companies and persons then engaged in mining under authority from the State exclusive rights to the territory in which their operations had been carried on previous to the passage of the Act, ten days after that date being allowed for the acceptance of the terms offered.

The Oak Point Mines Company at once accepted the terms of the Act and claimed the exclusive rights granted thereby.

The Act of 1876 was the nearest approach made by the State to a proper subdivision of its territory, but having been too long postponed and the general rights system being retained practically in all the streams save those occupied by the Coosaw and Oak Point companies, the plan was exceedingly defective and to that extent failed to subserve the interests of the State.

THE PROGRESS OF THE RIVER INDUSTRY.

The Marine and River Company, after enduring many vicissitudes and reorganizations, ceased operations in 1882. It had

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never been profitable to its stockholders and the efforts made under its last reorganization were fraught with disaster to many.

The Coosaw Company, in the meanwhile, after an initial period of disappointment and threatened disaster had been reorganized and, by extremely skilful management, had so successfully utilized the magnificent deposits embraced in its grant as to have proven a bonanza to its stockholders as well as to the State.

Of the 3,123,550 tons of rock that had been shipped by the river companies up to the end of 1894 the Coosaw Company had produced about 1,500,000 tons, or nearly one-half.

The following table, giving the production of river rock by years, shows more clearly and concisely than would be possible in words the rapid growth of the river industry from its inception in 1870 to its culmination in 1893 and 1894, after which time the results of the almost criminally senseless policy of the State towards the Coosaw Company, with the attendant litigation and the disastrous effects of the cyclone of 1893, became fully operative, and brought about the rapid decline and practical ruin of this branch of the industry.

TABLE OF SHIPMENTS OF RIVER ROCK FROM 1870 to 1894.

(Years ending September 1.)

	Tons.
1870	1,989
1871	17,655
1872	22,502
1873	45,777
1874	57,716
1875	67,969
1876	81,912
1877	126,569
1878	97,700
1879	98,586
1880	65,163
1881	124,541
1882	140,773
1883	129,318
1884	151,243
1885	171,671
1886	191,174
1887	202,757
1888	190,274

1889	212,102
1890	237,150
1891	169,293
1892	156,095
1893	249,339
1894	114,282
Total	3,123,550

In the meanwhile, besides the four companies mentioned above, other companies and individuals had been attracted by the opportunities offered by river mining. It is impracticable in this sketch to do more than mention the companies of a more or less permanent character.

Some of the individual miners received licenses from the State and paid their own royalties. Most of them, however, including all the small operators, worked under permits from the licensed companies, their production being sold to these companies, and the royalty thereon paid by them.

Amongst the companies may be mentioned, (with their fields of operation), the following:

Palmetto Phosphate Company—Ashley and Wando rivers.

Farmer's Phosphate Company—Bull and Coosaw rivers.

Sea Island Chemical Company—Johnson and Beaufort rivers.

Carolina Mining Company—Broad, Johnson, Morgan, Bull and Coosaw rivers.

Beaufort Phosphate Company—Beaufort and Coosaw rivers.

In 1890 the Coosaw, Sea Island and Oak Point Mines companies were consolidated under the name of the Coosaw Company, the object being partly a reduction of general expenses, but more especially a termination of the excessive competition which had brought great loss to all and was threatening to necessitate an early shut-down.

THE COOSAW LITIGATION.

Reference has been made to the litigation between the State and the Coosaw Company.

The original grant of twenty-one years, received by this company from the Marine and River Company, was to expire in 1891. The company claimed that the Act of 1876 had removed this limitation and given it a practically perpetual charter, conditioned only on the prompt payment of the royalty of one dollar per ton, a condition which it had always fulfilled promptly.

The question had been carefully investigated by Attorney

General Conner in 1877, and in an extremely interesting and valuable report on the subject he gave the opinion that the claim to perpetual rights was baseless.

On the expiration of the original grant, in 1891, the State carried the matter into the Courts and, after prolonged litigation, gained its cause and threw the territory open to the general rights miners.

While, under the decisions of the Courts, the State was entirely within its rights in pursuing this course, the folly of the step is and was equally clear, that is, so far as her true interests were concerned.

The causes of the action thus taken are not far to seek. The Coosaw Company after its first reorganization, as has been said, had developed a comprehensive and efficient system of mining and preparation by means of an expensive plant and a thoroughly ordered force of employees, whom it had made devoted to its interests.

It had been compelled to start practically *ab initio*, devising costly machinery, experimenting with it and adapting it to the service required. It had mined its territory systematically and, expecting to retain permanent control thereof, had worked it so as to economize the deposits and thus increase the revenue to be derived by the State.

The company had, it is true, received very large returns on its investment, but, as has already been stated, it had at the same time paid the State in royalties as much as the latter had received from all other operators combined. In a word, the history of the company had been an ample justification of the privileges it had enjoyed. and a striking testimony to the superiority of the exclusive rights system over the general rights system in force elsewhere.

The impression, produced by the great financial success of the company, that the deposits in Coosaw River had been originally almost unlimited, and that there was consequently a large supply remaining therein, together with the gradual exhaustion of the open territory, had led the outside miners to look with longing eyes on the forbidden land.

The assurances of the Coosaw Company to the contrary were considered false. Its statements, that the bulk of the better deposits had been exhausted, that though there was still remaining a considerable body of rock, it was of poorer quality and much of it contaminated with marl, that what was left of the good rock was in more or less isolated and small beds, in a word,

that at no time in its history had there been more need of the systematic efforts of a single operator, were all held to be only desperate attempts to retain, by plausible and baseless arguments, a rich and desirable monopoly, and were disregarded.

The opinions of men of high character, who could have confirmed the statements of the Coosaw Company, were not desired. Indeed a letter of this character written by one of the leading expert authorities of the State to the Governor was pigeon-holed by him and saw the light some time afterwards only by publication by the friends of the company.

Disregarded, also, were the recent discoveries of phosphates of various grades in Florida, in supposedly unlimited quantities and producible at a minimum of cost.

That the danger threatened thereby to the phosphate industry of South Carolina seemed so great, that it had been deemed advisable to send the Special Phosphate Assistant to visit the new discoveries, and that his report had shown that there was serious cause for alarm, were matters of no consequence.

The influences at work, together with the political necessities of unscrupulous demagogism, were too strong and prevailed over the interests of the State.

The General Assembly of 1890 passed an act creating a board of phosphate commissioners, who were directed, on the expiration of the original Coosaw grant, March 1, 1891, to take charge of the company's territory, to issue licenses to mine therein, and to enjoin all parties interfering with them or attempting to mine without their license.

The Act further provided that rock mined by such parties should be considered the property of the State and suits entered into to recover it; that all boats, vessels, dredges or other appliances used in such mining should be confiscated, that the officers of such companies should be subject to fine and imprisonment, and that the State should not be required to give bond in any such case it might be compelled to bring.

On March 1, 1891, the Coosaw Company, in view of the drastic nature of the penalties imposed by the Act, and unable to apply for a license, as such action would have been a virtual surrender of the perpetual rights it claimed to possess, suspended its operations.

A proposition made by the company to continue work, under the direction of the Board of Commissioners, until the matter should be decided in the Courts, without prejudice to the rights

of either party, was rejected by the State, without any regard to the necessary consequences of such rejection.

The works of the company were at once closed down and remained so until April of the following year.

The Carolina Mining Company and the Farmers' Mining Company received licenses from the board and entered the territory, but were at once served with injunctions obtained from the United States Court by the Coosaw Company and compelled to suspend operations.

CONSEQUENCES OF THE LITIGATION.

The loss of royalty to the State was very great, the damage to the company even greater. In addition to the loss of its earnings, it had to sustain the heavy expense of maintaining a large amount of valuable property subject to rapid deterioration when not in use.

Burdensome as these things were, they were as nothing compared with the loss of market that followed the suspension. The Florida river pebble deposits had been in operation for some years before the discovery of the hard rock and land pebble phosphates of that state. The grade of this Peace River pebble was a little higher than that of the Carolina river rock, of which it was a serious competitor.

Up to the time in question the high reputation that the latter rock had earned in Europe, together with some slight advantages in shipping, had enabled it to retain the field, and the Florida rock had not been able to make any serious inroads upon it.

The stoppage of the Carolina supply, of which the Coosaw Company had been the main producer, forced European consumers to supply their wants with the Florida product, and their experience therewith was so satisfactory that the preference which the Carolina rock had enjoyed was forever lost. The higher grade of the Florida rock, its cheaper cost of production and heavy output were sufficient to retain the foothold that had been gained, and the ground lost by the Carolina industry was never recovered.

The Coosaw Company resumed operations in April 1862, mining for a time in Mud Creek, a non-navigable stream, under an arrangement with the owners thereof. No royalty, of course, accrued to the State on this rock.

Later, the company accepted the situation and, with the other companies which had taken out licenses to mine therein, again entered its former territory and began an energetic struggle to regain a part, at least, of the lost trade.

Its efforts in this regard were paralyzed by the disastrous effects of the cyclone of August 31, 1893, which practically destroyed the plants of all the companies, and compelled them to apply to the Board of Phosphate Commissioners for relief, in the shape of a reduction of the royalty to fifty cents per ton; and they agreed that if this reduction were granted, they would rebuild their plants and renew their operations.

The petition, refused by the Board, was granted by the Legislature in December of the same year, and work was again started on January 1, 1894. The royalty was fixed at a minimum of 50 cents per ton, with a rising scale based on increased prices.

The consequences of the four months' delay, however, had been very serious. Uncertain as to the action of the Legislature, they had not only lost the four months' work, but had been unable to make contracts for future deliveries, and so what little ground had been regained was again in control of their competitors.

The consequence of this condition of things was such a great reduction in prices that, in 1895, the State Phosphate Inspector stated in his annual report that the companies were selling at a loss, and recommended a further reduction of royalty to twenty-five cents. The recommendation was disregarded.

The Carolina Mining Company was forced to the wall, and its property was sold piecemeal and scattered.

In 1896 additional competition from Tennessee and Algiers forced the companies to make another appeal to the Board of Commissioners. The Board, after obtaining the necessary authority from the Legislature, made the reduction asked for, but nullified its action by refusing to apply the reduction to the large stocks of rock on hand, in spite of notice from the Coosaw Company, which was the largest holder of such rock, that such refusal would necessitate a cessation of their operations, which followed in May, 1897.

In February 1898, the works were again started up and kept in operation until March 1902, when the struggle against the adverse conditions prevailing was decided to be hopeless, and the plant was closed down, dismantled and sold.

It is difficult to consider with patience the senseless folly of the course that precipitated this final outcome. Granted that the same result would have followed in time, in the natural course of events, still the end would have been materially delayed by a different course of action, and the financial results to the State have been materially larger. For, it must be remem-

bered, the whole Coosaw claim rested, admittedly, on the payment of the dollar royalty, and had it been allowed to continue undisturbed, the company would have been compelled to strain every nerve to meet this payment, with, of course, a much larger return to the State.

The Farmer's Mining Company, in 1897, became involved in the failure of other parties, and was ultimately sold to the Central Phosphate Company, which is still operating it, and which since the comparatively recent destruction by fire of the dredge of the Beaufort Phosphate Company, is the solitary surviving important operator in this once busy territory.

Since the first appearance of this article the Central Phosphate Company has discontinued operations. It recently made an offer to the State authorities to exploit some of the marsh deposits adjoining Coosaw River, conditioned on a reduction of the royalty. The reduction having been refused, no further steps, as far as can be learned, have been taken in the matter.

DEVELOPMENT OF THE LAND INDUSTRY.

The development of the land companies was rapid and important from the beginning of the industry, but being all practically private enterprises, they were less in the public eye, and offer less material for description.

The great importance of the Charleston Mining Company has already been alluded to, especially the success that had attended its efforts to gather a large and compact body of rich and shallow phosphate lands. The enterprise speedily became profitable and remained so until a change of management in 1891 or 1892 brought about a new state of affairs.

The new management was, unfortunately for the company, composed of men ignorant of the phosphate business, and who, while thus unhampered by the prejudices of experience, were equally unfamiliar with its lessons and results.

Carried away by wild opinions as to the dangers threatened to the value of their property—though of its real value, indeed, they could have had but a very hazy idea—by the recent Florida developments, and disregarding the advice of the experienced and skillful management which had been in successful conduct of the business of the company for so many years, they thought they had found a panacea for their anticipated troubles in a cheapening of the cost of production by the abandonment of their old plant at Lamb's, and the erection of a new, larger and more costly one on the Fetteressa plantation at Bee's Ferry.

Needless to relate, the conditions neither required nor justified this step, the most prominent result of which was the conversion of a large surplus into a bonded debt of the same amount, and only the great intrinsic value of the property prevented disaster in the more or less critical years that followed.

Ultimately, in 1901, it was sold to the Virginia-Carolina Chemical Company, which is now operating it. A strong commentary on the action of the former management is furnished by the fact that the present owners have found it advisable, the Fetteressa plant being in need of heavy repairs, to dismantle it and return to the former location, where they have just completed the erection of the largest phosphate plant in the world, the capacity of its washers being 1,200 tons per day.

Of the numerous land mines which have been operated at various times it is only practicable to give here a list of some of the more prominent. Amongst these have been the following:

Pacific Guano Company, Chisolm's Island.
Oak Point Mines Company, Kean's Neck.
Horse Shoe Mines, Ashepoo region.
Pon-Pon Mines, Edisto region.
Bulow Mines, near Stono River.
St. Andrew's Mines, near Stono River.
Bolton Mines, on Stono River.
Cherokee Mines, Ashley River.
Pinckney Mines, Ashley River.
Drayton Mines, Ashley River.
Pinckney Mines, Ashley River.
Gregg Mines, Ashley River.
Millbrook Mines, Ashley River.
Mount Holly Mines, Mount Holly.

Of these the Bulow and Pinckney properties are the only two that are being operated as entirely independent concerns.

The Bolton Mine, while operated by its owners or lessees, sells its whole output to the Virginia-Carolina Chemical Company.

The other mines have for the most part been purchased by the same company, the few exceptions having been either exhausted or shut down.

THE FERTILIZER COMPANIES.

The Wando Fertilizer Company, as has been stated, proceeded at once to utilize the new material in its manufacture.

It was not long left in sole possession of the field. On May 26, 1868, a charter was applied for in the name of "The

Sulphuric Acid and Superphosphate Company," the distinctive purpose of which was to make the sulphuric acid to be used in the manufacture of superphosphates.

On its acid chamber, the first to be erected south of Baltimore, work was begun August 21, 1868. The location selected for the work was on Town Creek, near the Cooper River, on the spot where the John Adams, the first frigate of the United States navy, was built, and which was subsequently the site of the Confederate navy ship yard. Here on December 8, 1868, the first sulphuric acid produced in Charleston was made. A second set of chambers was soon added, the two sets having a capacity of 180,000 cubic feet, and consuming 7,200 pounds of sulphur per twenty-four hours. One of the chambers of the second set was 140 by 30 by 25 feet, and at the time was the largest single chamber in the United States.

This plant was known as the "Etiwan Works," a name which was subsequently assumed by the company, which was capitalized at $350,000.

The Trade Review of Charleston, (published in 1873, by the Chamber of Commerce), shows that at that time the number of factories had been increased to six, namely:

Wando Company.
Sulphuric Acid and Superphosphate Company.
Pacific Guano Company.
Stono Company.
Wappoo Mills (J. B. Sardy's).
Atlantic Company.

The Wando Company, formed in June, 1867, had begun work, it will be remembered, in November of the same year, its factory being located in the city, and its sulphuric acid supply imported from the North. The city plant proving insufficient, a new factory and acid chamber were erected at the mines, convenient to the rock supply. The works were subsequently removed to a site on the Ashley River about five miles from the city. The capital stock of the company was $300,000. The works ultimately passed into the hands of the Virginia-Carolina Chemical Company.

The Sulphuric Acid and Superphosphate Company has already been described.

The Pacific Guano Company started operations in September, 1869. It operated its own mines, on Chisolm's Island, for many years, and in the Edisto region, not far from Jacksonboro, for a comparatively short time. Its fertilizer and acid plant were

located near the city, just above the forks of the road. Its capital stock was $1,000,000. It had a successful and eventful career, being finally involved in the failure of the Boston company, of which it was an offshoot.

The Atlantic Company, located on Ashley River, was started in December 1870, with $200,000 capital. It proved one of the most successful of the companies, and was ultimately sold to the Virginia-Carolina Chemical Company.

The Stono Company, also on Ashley River, had a capital stock of $160,000. and commenced operations in December, 1870. Though not so largely developed, ultimately, as the Atlantic works, its career was very similar to that of the latter company and its ending was the same.

J. B. Sardy mined in the Ashepoo region. His factory, Wappoo Mills, was located on Ashley River and Wappoo Cut, opposite Charleston. It afterward passed into the hands of Capt. C. C. Pinckney, who operated it for many years as an acid phosphate mill, the only one ever operated strictly as such in the State. It is now the property of the Virginia-Carolina Company.

An idea of the early activity of these works is given by the fact that up to July 1, 1872, their acid plants had produced 10,614 tons of sulphuric acid, valued at over $350,000. They had consumed 36,610 tons of rock and shipped 87,406 tons of fertilizer.

The figures for the amounts of acid produced and rocks consumed are interesting as showing the rather chary use of acid at the time, less than one-third of the amount now generally employed.

ANALYSES OF EARLY PRODUCTS.

The following analyses, made during the years 1869-71, are of interest, as showing the quality of the goods manufactured at that time.

It must be remembered, in this connection, that for the first two or three years no value was placed on reverted phosphoric acid, and it was not determined.

ANALYSIS OF FERTILIZER.

(Average of 7 Analyses.)

	P. C.
Soluble phosphoric acid	3.56
Insoluble phosphoric acid	10.17
Total phosphoric acid	13.73
Ammonia	2.45

Philip E. Chazal, E. M.

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In the seven analyses averaged above, the soluble phosphoric acid varied from 2.19 per cent. to 4.44 per cent. In four of the samples moisture was determined, the average being 20.19 per cent., and the range from 18.28 per cent. to 21.80 per cent.

FERTILIZERS MADE IN 1871.

	I.	II.	III.
	p. c.	p. c.	p. c.
Phosphoric acid, soluble	4.12	5.70	2.94
Phosphoric acid, reverted	2.60	2.47	1.76
Phosphoric acid, available	6.72	8.17	4.70
Phosphoric acid, insoluble	6.55	6.09	9.24
Phosphoric acid, total	13.27	14.26	13.94
Ammonia	3.09	3.26	2.22

ACID PHOSPHATE WITH POTASH (1871).

	P. C.
Phosphoric acid, soluble	9.94
Phosphoric acid, reverted	2.00
Phosphoric acid, available	11.94
Phosphoric acid, insoluble	4.11
Phosphoric acid, total	16.05
Potash	1.21

SUPERPHOSPHATES, (1871).

	I.	II.
	P. C.	P. C.
Phosphoric acid, soluble	4.50	8.79
Phosphoric acid, reverted	4.23	1.96
Phosphoric acid, available	8.73	10.75
Phosphoric acid, insoluble	8.64	3.88
Phosphoric acid, total	17.37	14.67

It was about this time that so-called "complete fertilizers" were first made, the analysis of one of which was as follows:

	P. C.
Phosphoric acid, soluble	6.06
Phosphoric acid, reverted	2.00
Phosphoric acid, available	8.06
Phosphoric acid, insoluble	4.47
Phosphoric acid total	12.53
Ammonia	3.00
Potash	1.50

At the period represented by the above analyses, the strength of the acid usually employed was 40° B. to 42° B., and it is therefore not surprising that, with the increased amount and strength of acid employed at the present time, modern products yield, in round numbers, three times the amount of soluble phosphoric acid and only one-third the amount of insoluble obtained in the older manufacture.

The progress so happily begun, was continued. As the years went on and the demand for fertilizers increased, the old companies enlarged their plants, and new ones were added to the list, two of which were erected at Beaufort and Port Royal. A list in the Trade Review of The News and Courier for 1880-84 shows that all the original companies, except the Sardy plant, were in operation and in addition gives the following new names:

Ashepoo Phosphate Company, capital $100,000, Ashley River.

Edisto Phosphate Company, capital $200,000, Cooper River.

Ashley Phosphate Company, capital $100,000, Ashley River.

Charleston Phosphate Company, capital $50,000, Ashley River.

Wilcox & Gibbes, manipulators, city.

Hume Bros. Phosphate Company, capital $500,000, near Beaufort.

Port Royal Phosphate Company, capital $100,000, near Port Royal.

Later on the following companies were added to the list in Charleston.

Berkeley Phosphate Company.

Imperial Fertilizer Company.

Chicora Fertilizer Company.

Royal Fertilizer Company, afterwards known as the Standard Phosphate Company.

Read Phosphate Company.

The Beaufort County companies changed their owners and were enlarged and known as the Hammond, Hull & Co., and Baldwin Works.

The Etiwan Works which had discontinued operations for several years, passed, ultimately, into the hands of a new set of owners, who, putting them in complete order, made a fresh start, under the old name, in April, 1900.

Outside of Charleston and Beaufort the records of the companies established and their outputs are apparently inaccessible, and only the principal ones can be mentioned, as follows:

Georgia Chemical Works, Pon-Pon.
Columbia Phosphate Company, Columbia.
Globe Phosphate Company, Columbia.
Royster Guano Company, Columbia.
Darlington Fertilizer Company, Darlington.
Anderson Oil and Fertilizer Company, Anderson.
Greenville Fertilizer Company, Greenville.
Blacksburg Company, Blacksburg.

It would be interesting and instructive, when viewed in the light of subsequent developments, to sketch the history of the fertilizer interests of the State; to show that, from the modest beginnings of 1867, the shipments of Charleston alone had reached 100,000 tons in 1881, 261,650 tons in 1890, and 437,138 tons, the high water mark, in 1898; to give an account of the periods of depression and prosperity and to study the causes producing them; to follow the companies in their futile efforts to arrive at some plan of mutual co-operation, if not of combination, and the final absorption of many of them by the Virginia-Carolina Chemical Company.

Even if the limits of this article permitted, it seems advisable not to attempt such a presentation at the present time, but to close the account, as so far given, with a list of the works now in operation in the State by the independent companies and the Virginia-Carolina Chemical Company.

The list, with the estimated capacity of each company, as nearly as could be ascertained, is as follows:

INDEPENDENT COMPANIES.

	Tons,
Ashepoo Fertilizer Company, Charleston	55,000
Etiwan Fertilizer Company, Charleston	30,000
Read Phosphate Company, Charleston	30,000

F. S. Royster Guano Company, Columbia	30,000
Anderson Oil and Fertilizer Company, Anderson	26,000
Total capacity, tons	171,000

To these must be added the following manipulating companies, which, having no acid plants, purchase their supplies of acid phosphate:

The W. C. MacMurphy Company, Charleston.

Combahee Fertilizer Company, Charleston.

Spartanburg Fertilizer Company, Spartanburg.

Anderson Phosphate and Oil Company, Seneca.

It is estimated that these companies have a capacity to prepare and ship, over and above their acid phosphate purchases, say 20,500 tons of goods.

Together the independent companies have a capacity of 191,500 tons, an amount equal to a little less than 60 per cent. of the requirements of the State, which last year amounted to about 325,000 tons.

VIRGINIA-CAROLINA CHEMICAL COMPANY.

	Tons.
Atlantic Works, Charleston	35,000
Chicora Works, Charleston	35,000
Imperial Works, Charleston	35,000
Standard Works, Charleston	70,000
Stono Works, Charleston	30,000
Wando Works, Charleston	25,000
Ashley Works, near Charleston	20,000
Georgia Chemical Works Pon-Pon	30,000
Baldwin Works, Port Royal	36,000
Columbia Works, Columbia	15,000
Globe Works, Columbia	18,000
Greenville Works, Greenville	16,000
Blacksburg Works, Blacksburg	12,000
Total capacity, tons	377,000

TOTAL CAPACITY IN STATE.

Independent companies,	171,000
Manipulating companies,	20,500
Virginia-Carolina Chemical Company,	377,000
Total capacity	568,500

CONCLUSION.

Although the story of the rise and progress of the South Carolina phosphate industry is a more than "thrice told tale", its full and detailed history is yet to be written.

In the preceding sketch an effort has been made to present only the more prominent facts connected with the subject in all its branches.

Lack of space is responsible for many omissions, the most conspicuous of which is the story of the men whose knowledge, energy and skill built up, advanced and successfully developed this great work, which was the salvation of the low-country of South Carolina, and to whom the State is even more indebted than to the distinguished scientists who opened the way to them.

Though much has been written in times gone by on the subject matter of this article, but little of it is in accessible form, and an important part of even the brief description here presented has been rendered possible only by the kindness of Professor Charles U. Shepard, Jr., in putting at the disposal of the writer manuscript notes, made many years since, which embody some of the early results of the varied and extensive labors which made Professor Shepard the foremost authority on phosphates in this country.

Except where otherwise credited the analyses given or referred to in this article were made by Professor Shepard or his assistants in his Laboratory for Analytical Chemistry, or by its successor, the Shepard Laboratory.

Philip E. Chazal, E. M.

Shepard Laboratory, Charleston, S. C.

NOTE.

As has been almost unavoidable from the way in which the necessary data had to be obtained, the annual estimates of the production and shipments of phosphate rock and fertilizers made by different parties have at times varied very widely, so much so as to make it impracticable to reconcile the differences, or decide between them.

These statistics have not been presented in the preceeding sketch, this branch of the subject having been assigned for treatment to Major Edward Willis, of Charleston, who, from the inception of the industry, has devoted particular attention to these questions, and has prepared the annual statement thereon for The News and Courier.

The following table is taken from his article as published in the Centennial Edition, and is of great interest as affording a condensed statement of the results arrived at by him. For the sake of comparison, there is also given a table showing the estimates made by the United States Geological Survey to, the end of the year 1902 only, the writer having been unable to obtain those for 1903.

TABLE SHOWING THE PHOSPHATE INDUSTRY

of South Carolina land and river rock mined and shipped to foreign and domestic ports, tons consumed, amount of royalty paid to State on river rock, and amount of fertilizers shipped annually from 1867 to 1903. (Years ending August 31st.)

Prepared by Major E. Willis for Centennial edition of The News & Courier.

Years.	Land Rock—Tons shipped U. S. ports.	River Rock—Tons shipped foreign ports.	Total Tons Rock	Exports Domestic Ports.	Consumed in Charleston	Exports to Foreign ports.	Royalty Paid State S. C. for Rock Mined from Rivers.	Shipment Fertilizers from Charleston—Tons.
1867	6	.....	6	6	.....	.....	$.....	12,822
1868	12,262	.....	12,262	7,500	3 600	205	.....	14,862
1869	31,958	.....	31,958	19,000	7,314	4,169	.....	29,789
1870	63,252	1,989	65,241	39,000	14,000	12,859	1,989	46,265
1871	56,533	17,655	74,188	24,805	7,108	42 283	17,655	22,589
1872	36,258	22,502	58,760	19,160	12,000	27,600	22,502	37,759
1873	33,426	45,777	79,203	33,737	18,431	27,035	45,700	56,298
1874	57,624	57 716	109,340	37,820	18,980	52,540	57,716	46,382
1875	54,821	67,969	122,970	32,560	20,000	70,546	67,970	50,837
1876	50,566	81,912	132,478	38,239	19,000	75,815	81,910	46,443
1877	36,461	126,569	163,030	47,500	13,600	102,677	126,570	45,766
1878	112,622	97,700	210,322	68,946	17,700	121,746	97,700	52,000
1879	100,779	98,586	199,365	60,899	18,960	119,566	98,586	60,000
1880	125,601	65,163	190.763	107,348	23,000	61,375	65,151	80,000
1881	142,193	124,541	266,734	157,824	38,900	70,668	124,541	102,525
1882	191,305	140,722	332,077	173,305	42,936	116,832	140,773	102,490
1883	210,000	180,000	378,380	210,000	42,620	123,000	129,319	130,000
1884	250,000	181,800	431,800	203,000	69,723	159,000	151,243	143,000
1885	225,000	184,000	409,000	158,000	67,000	184,000	171,676	150,000
1886	250,000	195,000	445,000	203,000	72,000	170,000	191,175	143,700
1887	262,000	228,000	480,000	200,000	85,000	195.100	202,757	131,901
1888	275,000	254,000	509,000	232,482	89,000	189,000	225,000	183,000
1889	290,500	220,000	510 500	308,643	91,450	136,000	212,100	181,990
1890	300,000	286,758	586,758	228,757	98,000	219,000	237.149	261,650
1891	375,000	197,949	572,949	274,083	102.250	126,748	185,000	287,975
1892	371,736	176,600	548,396	179,025	105,600	121,459	192,461	214,238
1893	316,456	312,113	618,569	183,814	162,309	178,068	249,338	325,618
1894	339,791	135,498	475,194	228,324	152,000	94,875	114,281	316,611
1895	276,778	154,597	431,375	174,990	131,000	125,385	174,400	159,526
1896	330,827	124,177	445,004	225,388	146,000	84,616	121,602	257,715
1897	322,272	121,846	434,118	195,710	162,000	76,408	39,801	374,494
1898	323,121	86,460	409,581	175,389	186,000	49,463	23,522	437,138
1899	355,165	125,991	481,076	223,986	164,000	89,870	39,042	332,912
1900	292,809	135,753	428,562	216,705	145,000	66,347	33,938	376,314
1901	232,704	93,564	327,768	125,357	180,000	24,231	25,521	429,378
1902	201,538	137,281	338,819	101,383	164,000	73,536	25,671	361,653
1903	242,852	127 971	360,823	78,218	225,000	57,605	15,262	356,560
	7,143,216	4,628,158	11,771,374	4,993,903	2,918,481	3,452,675	$3,712,062	6,362,191

ESTIMATES OF U. S. GEOLOGICAL SURVEY,

Phosphate rock (washed product) mined by the land and river mining companies of South Carolina.

Years ending May 31st.	Land Companies Long Tons	River Companies Long Tons	Total Long Tons
1867	6	.....	6
1868	12,262	.....	12,262
1869	31,958	.....	31,958
1870	63,252	1,989	65,241
1871	56,533	17,655	74,188
1872	36,258	22,502	58,760
1873	33,426	45,777	79,203
1874	51,624	57,716	109,340
1875	54,821	67,969	122,790
1876	50,566	81,912	132,478
1877	36,431	126,569	163,000
1878	112,622	97,700	210,322
1879	100,779	98,586	199,365
1880	125,601	65,162	190,763
1881	142,193	124,541	266,734
1882	191,305	140,772	332,077
1883	219,202	159,178	378,380
1884	250,297	181,482	431,779
1885	225,913	169,490	395,403
1885 June 1-Dec 31	149,400	128,389	277,789
1886	253,484	177,065	430,549
1887	261,658	218,900	480,558
1888	290,689	157,878	448,567
1889	329,543	212,102	541,645
1890	353,757	110,241	463,998
1891	344,978	130,528	475,506
1892	243,653	150,575	394,228
1893	308,435	194,129	502,564
1894	307,305	142,803	450,108
1895	270,560	161,415	431,975
1896	267,072	135,351	402,423
1897	267,380	90,900	358,280
1898	298,610	101,274	399,884
1899	223,949	132,701	356,650
1900	266,186	62,987	329,173
1901	225,189	95,992	321,181
1902	245,243	68,122	313,365
1903	.....	.....	.....
Totals..	6,702,140	3,930,352	10,632,492

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